POWER

Volume 50 New York October 7, 1919 *Number* 15

What We Are Really All Working For

Efficient Operation of Central Power Stations

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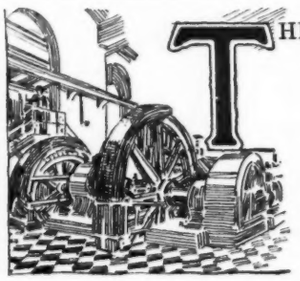
The efficient operation of central-power stations involves knowledge of accurate records, both daily and monthly, of the operation of every unit and of the station as a whole, systematic testing of all units to detect any falling off in efficiency and the exact cost data and the distribution of the total cost in the various departments of the plant. This article presents data and curves of importance to power-plant operators.



THE FIRST record necessary to the operation of any power plant is that of a load-curve sheet. This sheet should also have on it the capacity of the turbines or engines in service and available, number of boilers on the line and number available for service. It should be spotted as often as the load condition materially changes; in most cases every 15 min. will be found to be about right.

Then there should be a boiler-room sheet, to show the number of boilers on the line, banked and out of service each hour, when and what boilers were cleaned and blown down, temperature of the boiler-feed water, readings of feed-water meters, house-service meters, etc., for each watch, number of feed-water pumps on the line and the temperature of the discharge from each pump.

An engine-room sheet is also needed and should have the following data: Time, load, vacuum, barometer, circulating-water temperature in and out, hotwell temperature, steam pressure, temperature of steam, degrees of superheat, stage pressure, temperature of oil on bearings, temperature of oil to cooler and out. All these readings should be taken at least once every hour on every main unit.

If the plant uses salt water for circulating water, a condenser salt-test sheet should be kept. This record should show the degree of salt in the condensate from each condenser once every hour.

An electrical sheet should have on it the following data for every unit: load in kilowatts, power factor, amperes per phase, voltage, field amperes, frequency and armature temperature. No doubt the electrical sheet will need other data, but it is impossible to mention them here, for the class of service rendered will govern these items.

The daily station log sheet should be a summary of all the records taken during the day. A sample sheet of this record is shown in Fig. 1. This sheet was adopted by a large electric company in the New York district, and it enables the home office to keep in touch with the daily operation of each station in its district of operation.

The monthly generating report sheet (Fig. 2) should be a very comprehensive one of the operation of the station for the month. A comparison should be made with the operation of the station a year ago. This will enable the engineer in charge to see at a glance how each operating point compares with last year.

A monthly condenser-performance record should have on it the average daily readings of the following items: Date, load, vacuum (30-in. barometer), temperature of vacuum, temperature of hotwell, temperature of inlet water, temperature of outlet water, temperature rise, difference between temperature of vacuum and outlet water, pounds of steam condensed per hour, gallons of circulating water per minute (this item can be calculated from the temperature rise and the pounds of steam condensed per hour).

An example of what the monthly steam report sheet should contain is as follows:

STEAM REPORT FOR DECEMBER, 1914 (80,000 KW. STATION, PLANT FACTOR, 44 PER CENT.)

	Per Cent.
Steam used by main units	83.7392
Steam used by auxiliary units	13.6912
Steam used by cable testing	0.0520
Steam lost due to radiation	0.1692
Steam used for heating station	0.3744
Steam used for cleaning wiping towels, waste, etc	0.0166
Steam sold to contractors	0.0012
Steam used for fan and stoker engines on boilers	1.9008

All charts from curve-drawing instruments should be averaged and placed on racks where they can be easily reached, for these charts will furnish the engineer with valuable data on the daily operation of his station.

The daily average of all readings taken in the station should be kept in a card index. The record of repairs made to each individual machine, also the name-plate data of each machine, should be kept on these cards. This record will be found invaluable when it becomes necessary to look up back data or to order repair parts for the various machines.

The value of the yearly curves cannot be estimated, for they show clearly the daily operation of the station for the year. Fig. 3 shows the curves for condenser performance and Figs. 4, 5 and 6 show yearly curves.

Every engineer will find, once he starts to try to obtain records that will accurately show the operation of his station, that he will from time to time need various other records than those mentioned herein.

Starting a Systematic Test Method

As soon as a complete set of records has been started the next point that confronts an engineer is that of starting a systematic test method. Testing in a power station has in the past been left to the laboratory department of the company, and this has resulted in the accumulation of a mass of data largely theoretical, and these data have been of little value to the operating engineer as an aid to the efficient operation of his station.

Power-plant testing should be under the direction of men who, first of all, understand practical operation and, secondly, are well versed in the theoretical side of engineering. A man of such qualifications must be developed from men who, first of all, have had a thorough engineering education and who are willing to learn power-station operation by getting in and doing the actual work.

The first test to be made in any power plant is that of the station water-rate test. If the plant is a small one, all the feed water fed to the boilers or feed-water heaters can be weighed, or in a large plant the water hour, the temperature of boiler-feed water, temperature of steam, steam pressure, temperature of water feed and feed-water heater, temperature and pressure of the exhaust-steam fed to the feed-water heater, temperature

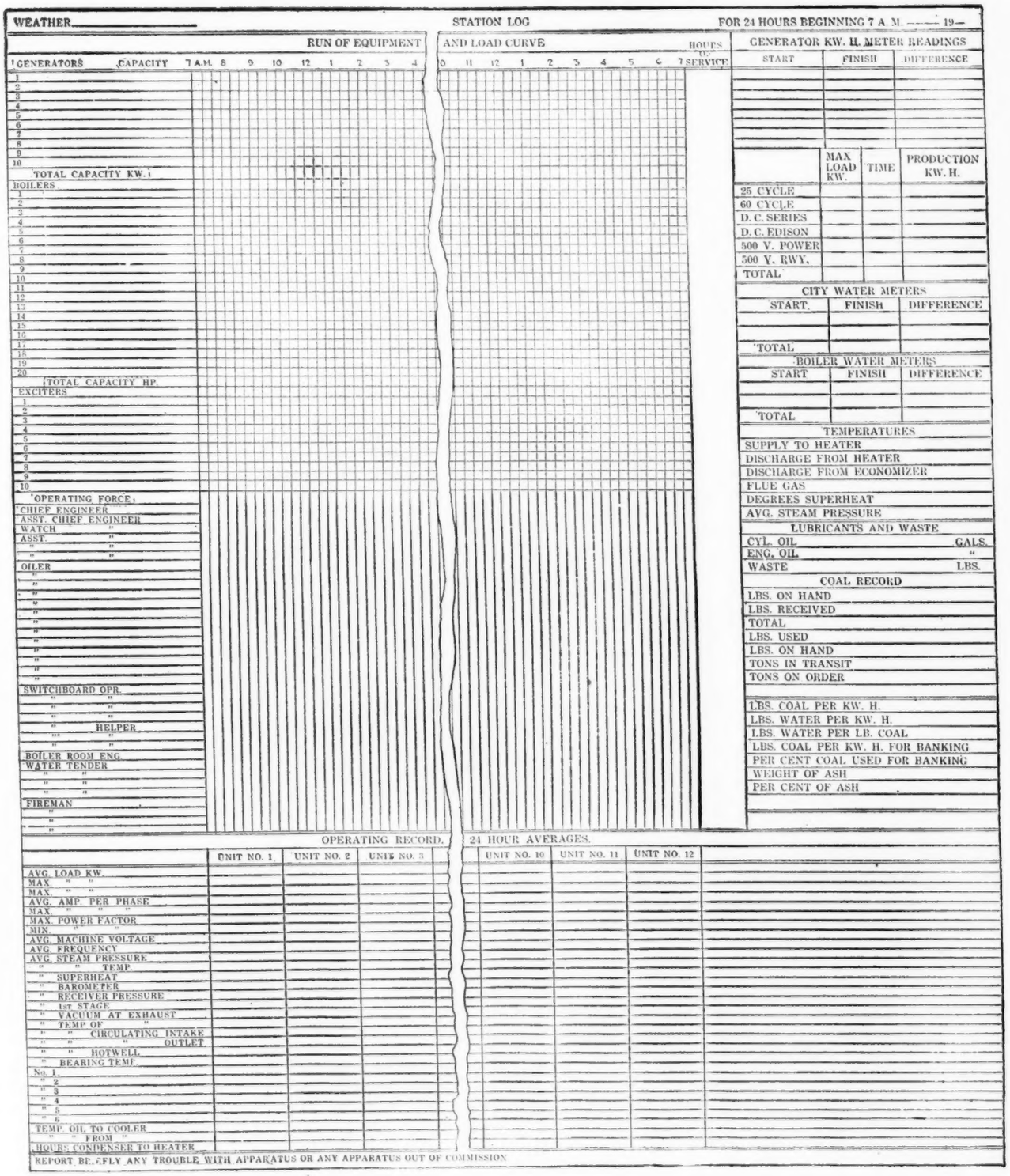


FIG. 1. SAMPLE SHEET OF DAILY STATION LOG SHEET

fed to the feed-water heaters can be calculated from a hook gage and a V-notch meter. The latter method is very reliable and is the one that is most generally used.

The output in kilowatt-hours should be read every of gases to and from the economizer, temperature of feed water to and from economizer, should be taken at least once every six minutes. The height of water in the boilers and feed-water heaters should be obtained once

every hour. The coal should be weighed as accurately as possible and a sample taken for every 50 tons burned. The refuse from the boilers should be weighed and a sample taken for every five tons. This test should last for a period of at least 48 hours, and notes should be kept of all operating conditions.

In the computation of the total water fed to the boilers (water fed to feed-water heaters plus the weight of the exhaust steam used to heat the feed water), the following formula can be used with very little error. Where

$$(Ws)(H - T_2) = (Ww)(T_2 - T_1) \text{ or}$$
$$(Wt - Ww)(H - T_2) = (Ww)(T_2 - T_1)$$

T_2 = Temperature of outlet water from heater; T_1 = Temperature of inlet water to heater; Wt = Total weight of the water and steam; Ww = Total weight of water; Ws = Total weight of steam; H = Total heat of exhaust steam.

Allowance should also be made for the height of water in the heater and below the starting levels of the same.

This test, when properly computed and rightly arranged (both in data and curve form), should show the following data on the operation of the station: Pounds of steam per kilowatt - hour; pounds of coal per kilowatt-hour; pounds of steam per pound of coal (actual and from and at); average temperature of steam; average steam pressure; temperature of boiler-feed water; temperature of water fed to heaters; temperature of flue gases to economizers; temperature rise of feed water in open heater; temperature rise of water in economizers; per cent. of boiler rating; kilowatt-hours per brake horsepower (maximum, minimum, average); B.t.u. per pound of coal; B.t.u. per pound of refuse; efficiency of boilers; B.t.u. per kilowatt-hour; and the net thermal efficiency of the power plant.

A table should be made up for future reference that will show the approximate losses in all parts of the station; for example, the following percentage losses were found, calculated or estimated in one plant:

	Per Cent.
Combustible matter in ash	2.5
Radiation and leakage of boilers	5.0
Gases rejected to chimney	14.0
Blow-off losses	1.5
Radiation and leakage of steam piping	1.5
Friction loss in auxiliary and turbines	2.0
Rejected to condenser	58.0
Electrical losses	1.2
Required for auxiliaries	6.5
Loss in each pound of coal	92.2
Regained by sending condensate back to heater and reheating it with steam from auxiliaries	5.0
Total energy delivered to bus	12.8

Just as soon as the station test has been completed, turbine tests should be started. These should be run under operating conditions and should last a 24-hour period. The load on the turbine should be varied so as to cover all the working points of the turbine. The following readings should be taken: Output (read on the watt-hour meter), voltage, amperes per phase, field current, armature temperatures, steam pressure, temperature of steam, stage pressure, temperature of cooling air in and out of generator, vacuum at exhaust, in condenser and hotwell, barometer, temperature of circulating water in and out, temperature of hotwell and speed of all pumps.

MONTHLY GENERATING STATION REPORT

Comparative Data for Months of ..... , 19.... and 19 ..... Station

CLASS OF GENERATORS OR SERVICE	Capacity—K. W.		Maximum Demand—K. W.		Production—K. W. H.		% of Total Output	
	19	19	19	19	19	19	19	19
A. C.—25 Cycle								
A. C.—60 Cycle Multiple								
A. C.—60 Cycle Series								
D. C.—Series Arc								
D. C.—Edison								
500 Volt Power								
500 Volt Railway								
Total for Station								
K. W. H. used in Generation								
Net Station Output								

	OPERATING RESULTS	19	19	% Increase	% Decrease
(9)	Average number of men employed daily				
(10)	Average daily wage per man				
(11)	Total Net Output in K. W. H.				
(12)	Maximum Demand in K. W.				
(13)	Average Hourly Output in K. W. H.				
(14)	Average Station Factor in				
(15)	Average Load Factor in				
(16)	Average daily K. W. H. Output				
(17)	Average daily K. W. H. per ma				
(18)	Average daily Boiler Horsepower Hours in Service				
(19)	Average daily Rated Boiler Horsepower Hours				
(20)	Average K. W. H. per Boiler Horsepower Hour in Service				
(21)	Average Per Cent. of Boiler Rating for month				
(22)	Lbs. of Bituminous Fuel used for Electrical Purposes				
(23)	Lbs. of Anthracite or Coke Breeze used for Electrical Purposes				
(24)	Total Lbs. of Fuel used for Electrical Purposes				
(25)	Anthracite or other Fuel used in Per Cent of Total Fuel				
(26)	Lbs. of Fuel used for Station use or other Purposes				
(27)	Total Lbs. of Water Evaporated by Boilers				
(28)	Lbs. of Fuel per K. W. H.				
(29)	Lbs. of Water per K. W. H.				
(30)	Lbs. of Water Evaporated per Lb. of Fuel (actual)				
(31)	Factor of Evaporation				
(32)	Lbs. of Water Evaporated per Lb. of Fuel (from and at 212°)				
(33)	Lbs. of Fuel used for Banking Boilers				
(34)	Per Cent of Fuel used for Banking Boilers				
(35)	Total Lbs. of Refuse from Fuel				
(36)	Per cent of Refuse to Total Fuel				
	Average Analysis of Fuel				
	Moisture %				
	Volatile Combustible %				
	Fixed Carbon %				
	Ash %				
		100.00	100.00		
	Sulphur (separately determined) %				
	B. T. U. per Lb. Fuel (air dried)				
	Superficial Moisture %				
(37)	B. T. U. per K. W. H.				
(38)	Net Thermal Efficiency of Plant %				
(39)	Average Steam Pressure—Lbs. per Sq. In.				
(40)	Average Degrees F. Superheat				
(42)	Average Vacuum (corrected to 30" Barometer)—Inches				
(43)	Average Temperature of Feed Water entering Boilers °F				
(44)	Total Cylinder Oil used gals.				
(45)	Total Engine Oil used gals.				
(46)	Total Dry Air Cylinder Oil used gals.				
(47)	Total Kerosene Oil used gals.				
(48)	Total Grease used Lbs.				
(49)	Total Waste, Wiping Cloths, or Rags used Lbs.				
(50)	Total Cheese Cloth used Yds.				

FIG. 2. A COMPREHENSIVE MONTHLY GENERATING REPORT SHEET

The amount of steam used by the turbine can be obtained from either of two methods, but better by the use of both—steam-flow meter on the steam main, weighing the condensate. If the condensate shows higher than the steam-flow meter, then it is possible that some of the circulating water is leaking into the condensate; if the condensing water is salty, the amount of leakage can be determined by a salt test of the condensate and of the circulating water. Silver nitrate salt test is the most reliable way of testing for salt.

A turbine test, when properly made, should show the following data for all operating points of the turbine and condenser: Pounds of steam used per hour; pounds of steam used per kilowatt-hour; stage pressures; armature temperature; temperature rise of generator cool-

ing air; vacuum (30-in. barometer); temperature rise of circulating water; temperature of condensate; inlet temperature of circulating water; outlet temperature of circulating water; temperature of vacuum; difference between temperature of vacuum and outlet water; difference between temperature of vacuum and hotwell; per cent. of vacuum; steam pressure; temperature of steam; gallons of circulating water per minute; and speed of all pumps.

These results should be shown graphically, and the condenser performance should be plotted to pounds of steam and not to kilowatt load. Figs. 7 and 8 show graphically the method of report tests for condensers and turbines respectively. All the main units should be tested in this manner and the steam consumption of all the auxiliaries should be determined. The auxiliaries can be tested with a portable steam-flow meter or a small portable condenser and weighing the condensate. Fig. 9 shows curves of a test on a boiler-feed pump.

As soon as all the main and auxiliary units have been tested, a composite water rate (that is, the main unit water rate plus the auxiliary water rate) should be made up for each unit on one sheet. This sheet should be given to the engineer and switchboard operators with instructions to carry the load on the most economical machines and at their best working points.

If an examination of the test results reveals the fact that all the units are not operating at their proper efficiency, an investigation should be started at once. First, the buckets or blades should be examined, and if they are found to be dirty they can be cleaned off by the

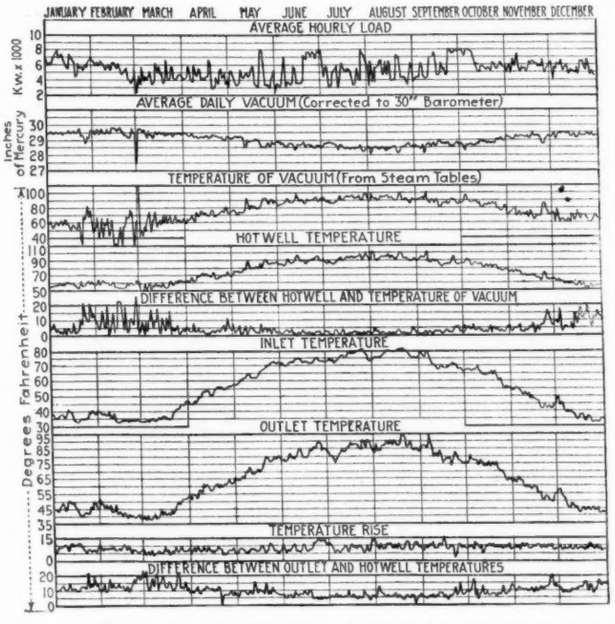

JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER
AVERAGE HOURLY LOAD
Kw x 1000
AVERAGE DAILY VACUUM (Corrected to 30" Barometer)
Inches of Mercury
TEMPERATURE OF VACUUM (From Steam Tables)
HOTWELL TEMPERATURE
DIFFERENCE BETWEEN HOTWELL AND TEMPERATURE OF VACUUM
INLET TEMPERATURE
OUTLET TEMPERATURE
Degrees Fahrenheit
TEMPERATURE RISE
DIFFERENCE BETWEEN OUTLET AND HOTWELL TEMPERATURES

FIG. 3. CURVE SHOWING OPERATION OF SURFACE CONDENSER ON A 10,000-KV.-A. TURBINE

injection of a few barrels of kerosene oil into the valve chest of the turbine when it is running at about half speed. The condensate should be dumped overboard until all traces of oil are out of it. This should be done to all turbines at least once every three months. Next, the condenser should be filled with water to determine if there are any air leaks in the condenser and turbine. If any leaks are present, the water will drop out of them and the location can be marked and repaired as soon as possible. The outside of the condenser tubes should be examined, and if a gum deposit is found on them the condenser should be filled up with a 4 or 5 per cent. solution of soda ash and boiled with steam for several hours. This will remove all foreign matter from the tubes and will not injure them in any way; but if the solution is of greater strength than 5 per cent., some action will be noticed on the tubes. The inside of the

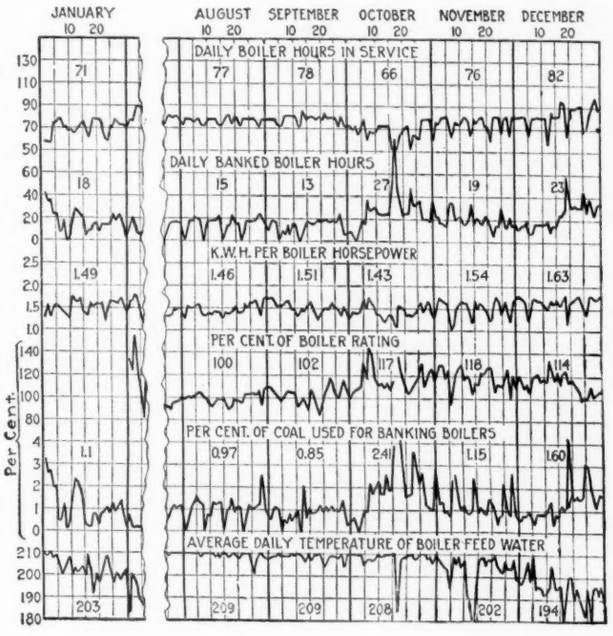

JANUARY
AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER
DAILY BOILER HOURS IN SERVICE
71 77 78 66 76 82
DAILY BANKED BOILER HOURS
18 15 13 27 19 23
K.W.H. PER BOILER HORSEPOWER
1.49 1.46 1.51 1.43 1.54 1.63
PER CENT. OF BOILER RATING
100 102 117 118 114
Per Cent.
PER CENT. OF COAL USED FOR BANKING BOILERS
1.1 0.97 0.85 2.41 1.15 1.60
AVERAGE DAILY TEMPERATURE OF BOILER FEED WATER
203 209 209 208 202 194

FIG. 4. YEARLY BOILER-ROOM CURVES

tubes should be examined, and if they are found to be dirty they should be cleaned at once.

The cleaning of condensers should be a regular operating job; when to clean them can be told by the temperature rise of the circulating water. Fig. 10 is a curve showing the amount of circulating water needed for various temperature rises with varying amounts of steam condensed per hour.

When the inspection has been completed, the turbines should be tested again, and if they do not come up to their proper efficiency experiments should be started to determine if the design of the turbine or condenser can be changed to produce the desired efficiency.

At this point a test should be made to determine the effect of various vacua on the water rate of the turbine and also the effect of various sized air leaks on the vacuum. Fig. 11 is a curve that shows the effect of vacuum on the water rate of a 3000-kw. vertical turbine.

The next point to investigate would be that of the steam piping. A line diagram should be made of all the piping to determine if any changes can be made that will insure a more flexible piping system and if the piping is properly covered. The approximate relative value of different pipe coverings are:

Covering	Thickness, In.	B.t.u. Loss per Hour per Sq.Ft. per Degree of Average Difference in Temperature
Uncovered pipe	....	2.71
85 per cent. magnesia	1.18	0.418
85 per cent. magnesia, 2-in. section, ½ in. block	2.71	0.288
85 per cent. magnesia, two 1-in. sections	2.50	0.294
Hair felt	0.82	0.422
Rock wool	1.60	0.256
Mineral wool	1.30	0.285

A test should next be run on the open heaters to determine if they are properly doing their work. The following readings should be observed: Total water feed to heaters, total exhaust steam feed to heaters, temperature of exhaust steam, pressure of exhaust steam, height of water carried in heater, temperature of water feed to heater, temperature of water from heater. This test should last twenty-four hours. The various drips and traps that discharge into the heater should be placed so that they will discharge the water and steam into the heater without interfering with the flow of inlet water to the heater pans.

The boilers should be tested; that is, each type of boiler and stoker in use in the plant should have a complete test made on it. First, a maximum capacity test, which should last for at least four hours. Next, a series of tests, each of four hours' duration, should be made with varying draft pressures, so that when all the tests are completed curves can be made up for the entire operating range of the boiler and stoker. The following facts should be determined or read in every boiler test, and curves should be made for each item: Pounds of coal burned per hour; pounds of coal burned per square foot of grate surface; pounds of air per pound of combustible; percentage of ash and refuse to total coal burned; coal analysis (sample for every ten tons of coal burned); ash analysis (sample for every two tons of ash); flue-gas analysis (gas sample taken every ten minutes); draft between boiler and damper; draft in furnace (over the fire); draft in ashpit; draft readings along the flow of the gases; temperature of furnace; temperatures along the flow of gases; temperature of gases in uptake; temperature of steam; temperature of boiler-feed water; pressure of steam; pounds of water evaporated per hour; percentage of boiler rating; apparent evaporation; equivalent evaporation; equivalent evaporation per square foot of heating surface; efficiency of boiler in percentage; efficiency of boiler and furnace; efficiency of gasification of fuel; cost of steam per 1000 lb.; and method of firing; that is, thickness of fire, speed of stoker shafting, etc.

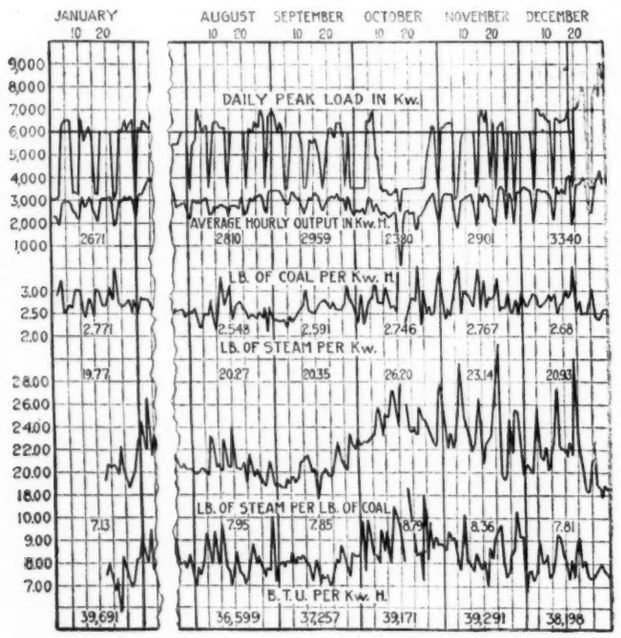


FIG. 5. YEARLY STATION CURVE

The boiler setting should be examined for tightness and proper heat insulation, and if any air leaks are found they should be stopped at once. The tubes should be inspected for cleanliness both inside and outside.

Draft and temperature readings should be taken on each boiler along the flow of gases to determine if the baffles and bridge-walls are in good condition. In

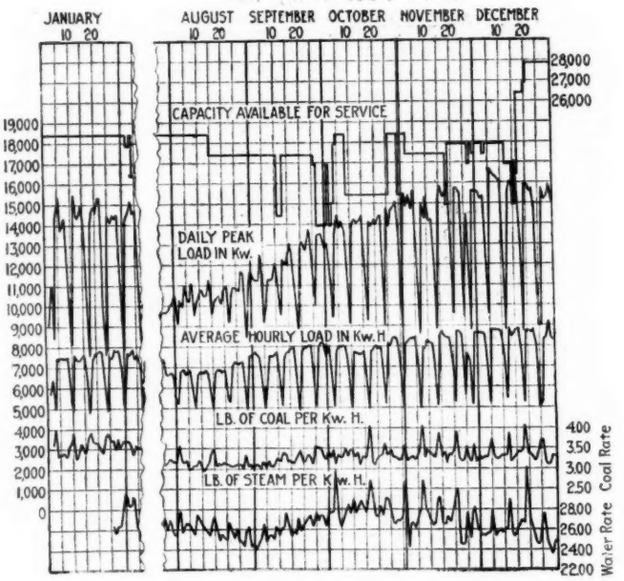


FIG. 6. YEARLY DIVISION LOAD CURVES

Fig. 12 two curves are given which show the temperatures obtained with good and bad baffles. The top curve shows that the baffles are in good shape; the bottom curve indicates that the baffle between the first and second pass is bad.

The design and construction of the furnace should be examined. No precise rule can be made for the design of the furnace, as local plant conditions, such as quality of coal, force of draft, etc., will greatly affect the design. In regard to the material used in the construction, it will be found that a poor quality of brick that is uniform as to size will outlast a good quality that is not uniform. It has been found that the best baffle is constructed of two courses of firebrick with a $\frac{1}{2}$-in. section of asbestos millboard between the brick.

A test should be run to determine the actual amount of coal per brake horsepower per hour that is necessary to properly bank a boiler; that is, to keep it up to boiler pressure. This test should last at least 24 hours to avoid the error due to the heat being stored up in the boiler settings. The following table shows the approximate amounts of coal needed per hour to properly bank various types of boilers:

	Lb. per Hour
Babcock & Wilcox boiler, Roney stoker, 600 b.hp.	162
Babcock & Wilcox boiler, Bayonne stoker, 600 b.hp.	201
Edge Moor boiler, hand-fired, 600 b.hp.	115
Heine boiler, 300 b.hp.	53
Stewart boiler, 150 b.hp.	19

A table should be prepared showing the rating at which it is desired to operate the boilers. This table should show the following items in regards to operating points: Draft at damper, draft over the fire, draft in ashpit, speed of stoker shafting, thickness of fires, how often to clean fires, water level in boilers, pounds of coal required to bank each type of boiler per hour, how often the boilers are to be blown down (this point should be

determined by a daily salt test on the boilers, a safe working figure for boilers being 25 to 30 grains per U. S. gallon, while for condensers the salt should not run over 5 to 6 grains per U. S. gallon), when tubes are to be cleaned, and the number of boilers required for various loads. This table should be given to the boiler-

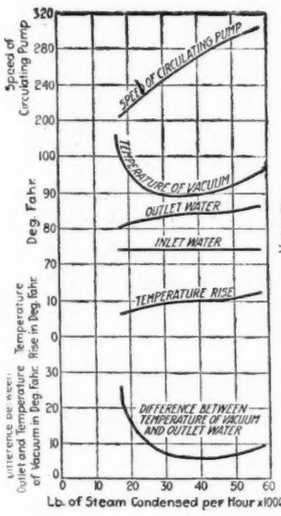

Speed of Circulating Pump
SPEED OF CIRCULATING PUMP
Deg. Fahr
TEMPERATURE OF VACUUM
OUTLET WATER
INLET WATER
Temperature Rise in Deg. Fahr.
TEMPERATURE RISE
Difference between Outlet and Temperature of Vacuum in Deg. Fahr.
DIFFERENCE BETWEEN TEMPERATURE OF VACUUM AND OUTLET WATER
Lb. of Steam Condensed per Hour x1000

FIG. 7. CURVES OF CONDENSER TEST

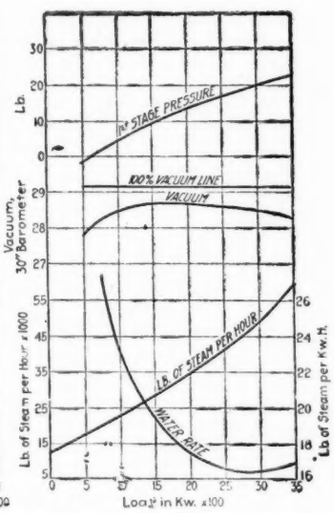


FIG. 8. CURVES OF TURBINE TEST

room engineer and a man placed in the boiler room to instruct the engineer and firemen in regard to the instructions and to see that they are carried out.

Care should be exercised to see that at all times the boiler feed-water temperature is carried at the highest figure possible. If at times it is found that too much or too little steam is obtained for heating the feed water, then it is advisable to install a heat-balance valve on one of the turbines, or on as many as are needed. This valve will take steam from or deliver steam to the secondary stages of the turbine and will maintain the proper amount of steam in the exhaust-steam main. Or it may be found that a great deal of hot water is being lost because the open heater is overflowing. If a water seal is put on the overflow line, it will be found to remedy this trouble. Fig. 13 shows the saving in per cent. due to increased feed-water temperature.

A series of tests should be run to determine the right kind of oil for the various machines that are to be lubricated. The results obtained from these tests should be of such a nature that specifications for the purchase of oil can be made from the data obtained. Oil specifications should contain at the least the following items: Composition; per cent. of free acid; specific gravity at 27.6 deg. C.; flashing point, deg. C.; burning point, deg. C.; chill point, deg. C.; loss at 80 deg. C. in five hours; viscosity, compared to water at various temperatures; gumming value, distance flowed down a glass plane; grade of $3\frac{1}{2}$ per cent. and coefficient of friction.

As a general rule a large amount of oil can be saved or reclaimed by the use of any of the oil and waste cleaners on the market; the oil obtained from the cleaner or press can be filtered and used again in various machines that do not require first-class oil.

With regard to the maintenance of the various units in the plant it will be found that if a systematic method of testing and inspection of all units is put in operation, the maintenance cost will be reduced to a minimum, but if by increasing the maintenance cost the operating cost can be reduced, the net result will be a decreased current cost. The installation of a good machine shop will enable many repairs to be made at a reduction in cost, because parts can be made when other work is slack, and then repairs can be made the instant they are needed; also in a power-plant machine shop a small overhead cost is possible.

The labor problem in power-station work is one that demands study, but in most cases it will be found that if a diagrammatic sketch is made up, showing the duties of each man and the location of the units he is to look after, it will enable one to decide if the duties are rightly apportioned.

If it is possible at any time to shut down the plant for a period of ten hours, a test should be made to determine the amount of steam that is necessary to take care of the leaks and radiation. This test is generally made as follows: First, all the boilers are filled—that is, each boiler should have a full glass of water—then all the pumps are shut down and enough fire is kept under the boilers to keep the steam up to working pressure. Care should be taken that the safety valves do not blow and that the blowoff valves do not leak. Readings should be taken every hour of the height of water in the drums and of the amount of coal used, notes should be taken of all leaks that are observed in any part of the plant. The amount of steam necessary to take care of the leaks and radiation in the plant can be calculated from the number of inches of water used up in the boilers. This test is not absolutely accurate, but it will be found to be a good approximation of these losses.

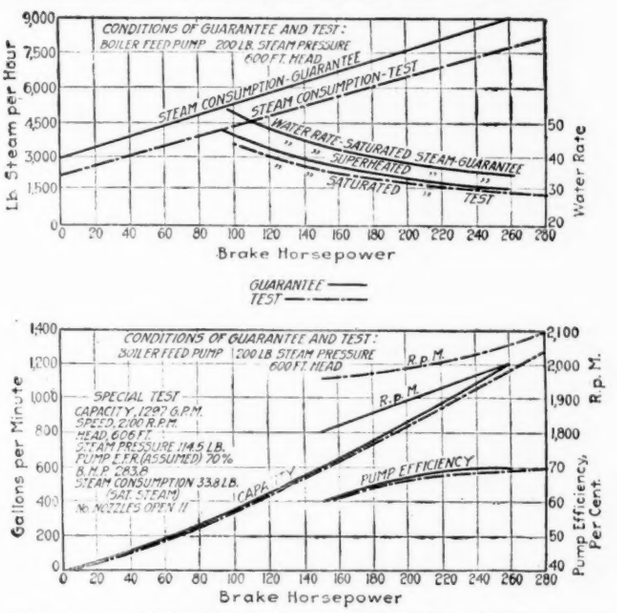


FIG. 9. GRAPHIC METHOD OF SHOWING BOILER-FEED-PUMP TEST

If the total pounds of coal and total pounds of water used daily for a period of a year are available, some valuable curves can be obtained by spotting the foregoing figures against the daily output. These curves will show the coal rate and water rate and evaporation for varying outputs and will also show the pounds of coal and water used daily to be ready to pick up the load. They can be used to determine whether the station is running at a better efficiency than it was in the year the curves where made. See Fig. 14.

Cost data play an important part in power-station work; that is, the cost sheet shows the results of all attempts made to run the station in an efficient manner. A cost system should be devised in detail, so that there can be no doubt as to the proper account each bill should be charged to or against. The monthly cost of current is simply an indication as to the approximate cost of

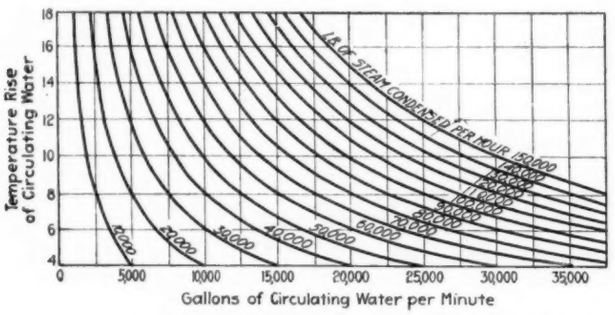


FIG. 10. CIRCULATING WATER REQUIRED FOR TEMPERATURE RISE WITH VARIOUS AMOUNT OF STEAM CONDENSED PER HOUR

current. This is due to the fact that in a great many cases work done in one month is often not charged out till the following month, and bills for material do not arrive in time to charge them to the proper month. The yearly cost can be made very accurate if attention is given to it. The various accounts that are generally used in a power station cost system and what charges are charged to each account follow in brief form:

The boiler-room labor account should include the cost of labor in the boiler room and elsewhere about the premises having to do with the making of steam.

The turbine or engine-room labor account should include the labor of the chief engineer, engineers, helpers, oilers, wipers, machinists, etc.

The account relating to electrical labor includes the cost of all labor in connection with the electrical generating apparatus and devices, beginning with the generators direct-connected or belted to prime movers and including the switchboard, feeder terminal board, and

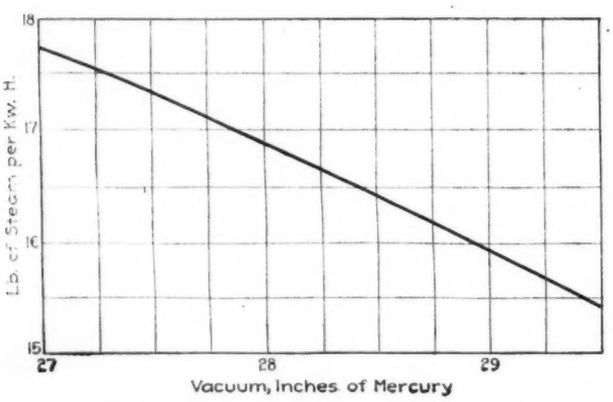


FIG. 11. CURVE SHOWING EFFECT OF VACUUM ON TURBINE WATER RATE

to where the electrical current leaves the station for transmission and distribution.

Supervision includes salaries and personal expenses of superintendents and assistants, general operating officials and general engineering staff chargeable to operation.

Operating labor includes the sum of all the aforementioned accounts, plus clerks' hire, janitors and watchmen.

The coal account includes the cost of fuel and all labor expended on it till it reaches the bunkers; water account includes the cost of water for feed water and condensers, also the cost of boiler compound; lubricants account includes the cost of grease, engine oil, cylinder oil, dynamo oil, graphite, freight and cartage. The miscellaneous-material account is for material which the accounts mentioned do not cover. The total operating-material account is the total of all operating-material accounts, and the total operation is the sum of operating labor and material.

Building labor and material account includes the labor and material used in making repairs to buildings and structures used for power-station purposes. Boiler-room labor and material account includes the labor and material charges of repairing boilers, furnaces and auxiliary apparatus, such as feed-water pumps, blower engines and fans, coal conveyors, filters, heaters,

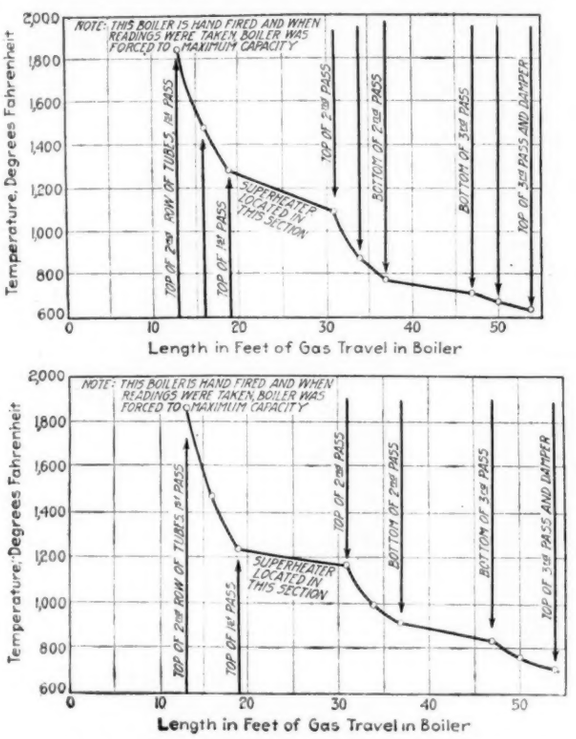

NOTE: THIS BOILER IS HAND FIRED AND WHEN READINGS WERE TAKEN, BOILER WAS FORCED TO MAXIMUM CAPACITY
Temperature, Degrees Fahrenheit
TOP OF 2nd ROW OF TUBES, 1st PASS
TOP OF 1st PASS
SUPERHEATER LOCATED IN THIS SECTION
TOP OF 2nd PASS
BOTTOM OF 2nd PASS
BOTTOM OF 3rd PASS
TOP OF 3rd PASS AND DAMPER
Length in Feet of Gas Travel in Boiler

FIG. 12. CURVES SHOWING TEMPERATURES IN BOILER PASSES

economizers, stoker engines, etc. Turbine-room labor and material account includes the labor and material used in making repairs to steam turbines, condensers, air, circulating and oil pumps. Electrical labor and material includes the labor and material charges on all electrical apparatus. Piping labor and material account includes all labor and material charges on the piping system. Miscellaneous labor and material account includes charges not covered by the foregoing accounts.

Total maintenance labor is the total of all labor charges for maintenance. Total maintenance material is the total of all material charges for maintenance. Total maintenance is the sum of maintenance labor and material.

Total current cost is the sum of all labor and material expended in the generation of power.

Cost per kilowatt-hour is the total cost of current

divided by the total output, minus the current used in the generation of current. Pounds of coal per kilowatt-hours is the total pounds of coal used divided by the total output, minus the current used in the generation of current. Cost of coal per ton (2000 lb.) is the total

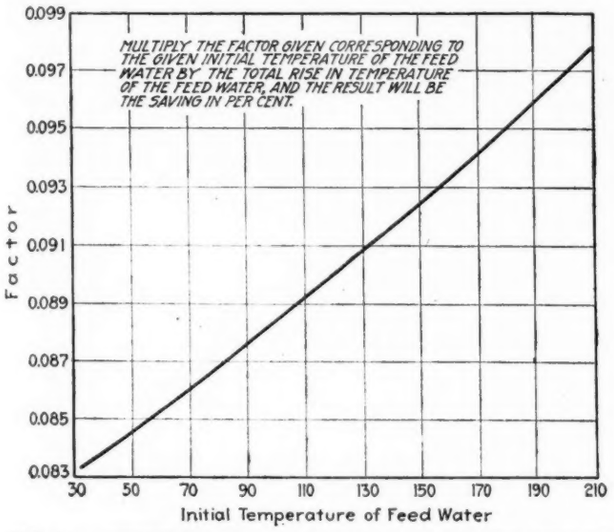

MULTIPLY THE FACTOR GIVEN CORRESPONDING TO THE GIVEN INITIAL TEMPERATURE OF THE FEED WATER BY THE TOTAL RISE IN TEMPERATURE OF THE FEED WATER, AND THE RESULT WILL BE THE SAVING IN PER CENT.
Factor
0.099
0.097
0.095
0.093
0.091
0.089
0.087
0.085
0.083
30 50 70 90 110 130 150 170 190 210
Initial Temperature of Feed Water

FIG. 13. CURVE SHOWING SAVING IN PER CENT. DUE TO INCREASED FEED-WATER TEMPERATURE

cost of the coal account divided by the number of tons of coal used.

It is of value to know the percentage distribution of the current cost in the various departments, for it en-

TABLE I. PERCENTAGE DISTRIBUTION OF CURRENT COST IN VARIOUS POWER STATIONS

Name of Account	Plant A	Plant B	Plant C	Plant D	Plant E	Plant F
Operation						
Labor:						
Boiler room	7.920	8.555	9.109	14.698	4.673	8.976
Turbine room	3.264	3.042	6.275	5.921	2.702	4.737
Electrical	3.356	0.950	1.215	2.172	1.019	2.521
Supervision, janitors, watchmen	4.350	1.331	1.215	4.436	1.085	0.180
Material:						
Coal	64.156	63.118	70.648	44.765	77.453	66.214
Water	1.980	6.273	0.202	2.011	0.709	3.463
Lubricants	0.396	0.380	0.405	0.558	0.243	0.734
Miscellaneous material	0.792	0.190	1.215	1.723	1.463	0.997
Miscellaneous charges	0.198	1.521	1.012	.....	.....	.....
Maintenance						
Labor:						
Building	0.198	0.570	0.607	0.383	0.664	0.152
Boiler room	2.376	2.281	0.809	1.165	1.107	1.593
Turbine room	0.396	0.571	0.202	0.543	0.111	0.346
Auxiliary apparatus	1.386	0.762	0.465	1.931	0.243	1.510
Electrical	0.594	0.380	0.000	0.255	0.089	1.565
Piping	0.000	0.380	0.405	1.835	0.310	0.526
Miscellaneous	0.198	0.190	0.202	0.000	0.000	0.222
Material:						
Building	0.396	0.380	0.202	2.127	1.373	0.000
Boiler room	2.376	6.273	1.417	2.170	3.610	1.053
Turbine room	0.198	0.571	0.202	0.192	0.000	0.678
Auxiliary apparatus	0.594	0.762	0.809	2.106	0.399	0.858
Electrical	0.000	0.574	0.405	0.144	0.975	3.546
Piping	0.000	0.190	0.809	7.804	0.266	0.152
Miscellaneous	0.396	3.190	0.607	0.000	0.022	0.000
Total operating labor	19.208	13.878	17.814	27.226	9.479	16.415
Total operating material	67.525	71.483	73.481	49.058	79.867	71.408
Total operation	86.732	85.361	91.295	76.284	89.346	87.823
Total maintenance labor	5.148	5.134	2.631	6.112	2.525	5.887
Total maintenance material	3.960	8.938	4.453	12.544	6.644	6.288
Total maintenance	9.108	14.072	7.084	18.656	9.169	12.195
Other charges to power station account	4.159	0.571	1.620	5.060	1.484	0.000
Total cost of current	100	100	100	100	100	100
Coal per kw.-hr., lb.	2.72	2.81	3.004	3.5171	2.443	3.23
Cost of coal per ton (2,000 lb.)	$2.38	$2.377	$2.32	$1.61	$2.715	$2.959
Average daily output (kw.-hr.)	261,400	329,800	90,800	131,100	638,300	166,300
Total cost of current compared to Plant E, per cent	112	111	109	139	100	160

ables the engineer in charge to tell the amount of his time that should be devoted to each department.

In Table I the percentage-cost distribution for several power stations is given. It will be seen that local conditions or differences of operation greatly affect the current cost.

In Table II two years are compared. In the first

TABLE II. COMPARATIVE YEARLY COST SHEET, PLANT "E"

Name of Account Operation	Year, Per Cent.	Year, Per Cent.	Per Cent. Increase	Per Cent. Decrease
Labor:				
Boiler room	4.673	4.187	.....	16.587
Turbine room	2.702	3.164	9.024	.....
Electrical	1.019	1.025	.....	6.522
Supervision, janitors, etc	1.085	1.213	4.082	.....
Material:				
Coal	77.453	76.260	.....	8.321
Water	0.709	0.666	.....	12.500
Lubricants	0.243	0.285	9.090	.....
Miscellaneous material	1.463	1.401	.....	10.606
Maintenance				
Labor:				
Building	0.664	0.856	20.000	.....
Boiler room	1.107	1.142	.....	4.00
Turbine room	0.111	0.190	60.000	.....
Auxiliary apparatus	0.243	0.499	90.000	.....
Electrical	0.089	0.095	.....	.....
Piping	0.310	0.594	78.571	.....
Material:				
Building	1.373	0.737	.....	50.000
Boiler room	3.610	3.300	.....	14.110
Turbine room	0.000	0.119	.....	.....
Auxiliary apparatus	0.399	1.261	194.44	.....
Electrical	0.975	0.689	.....	34.091
Piping	0.266	0.807	183.330	.....
Miscellaneous	0.022	0.024	.....	.....
Total operating labor	9.479	9.586	5.841	.....
Total operating material	79.8670	78.615	.....	8.348
Total operation	89.346	88.201	.....	8.081
Total maintenance labor	2.525	3.377	24.561	.....
Total maintenance material	6.644	6.969	2.33	.....
Total maintenance	9.169	10.347	5.072	.....
Total decrease in current cost	.....	6.880	.....	.....
Lb. of coal per kw.-hr	2.443	2.210	.....	9.537
Average daily output, kw.-hr	638,300	744,470	16.616	.....
Cost of coal per ton of 2,000 lb.	$2.715	$2.783	2.505	.....

All the foregoing figures are percentage figures of the cost per kw.-hr.

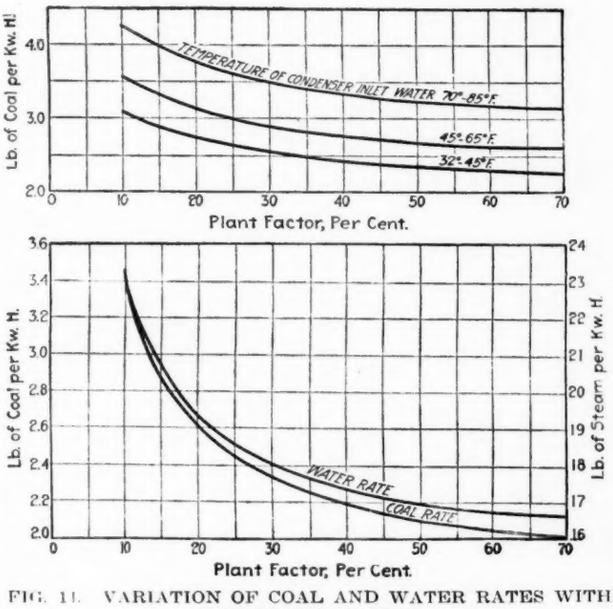
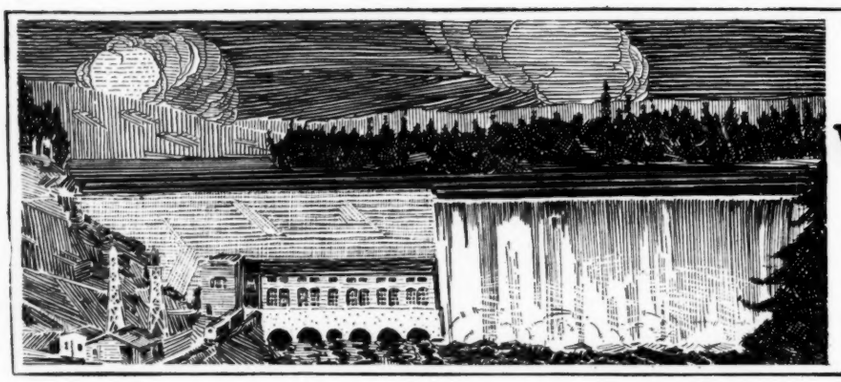

Lb. of Coal per Kw. H.
4.0
3.0
2.0
TEMPERATURE OF CONDENSER INLET WATER 70°-85°F.
45°-65°F.
32°-45°F.
0 10 20 30 40 50 60 70
Plant Factor, Per Cent.
Lb. of Coal per Kw. H.
Lb. of Steam per Kw. H.
3.6 3.4 3.2 3.0 2.8 2.6 2.4 2.2 2.0
24 23 22 21 20 19 18 17 16
WATER RATE
COAL RATE
0 10 20 30 40 50 60 70
Plant Factor, Per Cent.

FIG. 11. VARIATION OF COAL AND WATER RATES WITH THE PLANT FACTOR

year no attempt had been made to operate the power station in an efficient manner; in the second year a systematic scheme for the operation of the station was started. This table shows just what was done in each department and what results were accomplished, and the results obtained were convincing enough to decide that the right method for the operation of this particular station had been found.

The methods mentioned in this article do not necessarily hold for all plants, but they are presented as suggestions for those who are desirous of working up power-plant data.



POP'S WATER-POWER COURSE

By

John S. Carpenter

"SHALL we talk about the plain an' needle nozzle, along with somethin' on the Pelton bucket?" asked Pop of Jimmy.

"You know me, Pop. I'm strong for your hydraulic chatter any time."

"That bein' the case, son, we'll tear loose. This critter I'm a-drawin' (Fig. 1) is a plain nozzle. This is the most primitive form for deliverin' water to a wheel an' also the cheapest. The inlet is made large

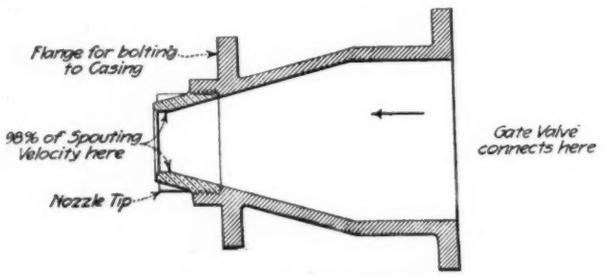


FIG. 1. PLAIN NOZZLE

enough to let the water pass with a velocity not exceedin' about that due to 3 per cent. of the head. At the discharge they usually 'lows about 2 per cent. more area than is theoretically needed so as to make some allowance for friction, it bein' gen'ly assumed that the velocity is less by 2 per cent. an' addin' the extry area lets the full water quantity through. The smallest area of the nozzle is made short, and then it should increase quite rapidly in diameter with a nice easy curve. The inside should be bored out an' then polished so that the friction, which increases as the square of the velocity an' directly as the roughness coefficient, is kept low."

"Can they regulate the size of the stream in a plain nozzle like this with some sort of a shutter like that on a camera? With such a hickey it would seem that you could get any size stream within the range of the nozzle diameter."

"They tried that very thing," declared Pop, "along with half a hundred other things that looked promisin'. The main trouble with the critter you jes' proposed is that the pressure, when it is anything at all, is likely to blow the hull dern thing to smithereens, not to speak of such triflin' faults as leakage when closed and stream distortion at almost any openin'. Any device that proposes to shet off the water supply abruptly, by which I means by throttling with a thing on the gate-valve principle, you can bank on as bein' all bunk. Them things has all the benefits of a sudden contraction in 'em in some shape or other an' it never fails to produce whirls an' eddies in the flow."

"Then what kind of a thing can be used to regulate the area of the stream without distortion of the jet and making a lot of friction?"

"Your question leads up quite purty to the needle nozzle. This sketch (Fig. 2) almost explains itself. The idee is that the bulb-shaped dingus is moved in or out as you wants to increase or decrease the size of the stream or jet. It gives an idea of the proportions of the thing with the figgers on the sketch, based on the size of the jet needed by the wheel. A few degrees change in the angles or a little difference in the proportions would never be so serious as to affect the good qualities of the nozzle so long as the point of inflection of the bulb—which is the place marked *A* where the curvature of the bulb changes from convex to concave—is inside of the bore of the tip. The other important fact about this thing is that it should be bored out to a true curve and then polished. The high velocities and the fact that the water often carries sand sometimes plays the divil with the nozzle tips; so in such cases they makes them of steel castings or very tough bronze. The needles are usually made of machinery steel unless the water carries acid in solution. When you see a needle badly worn or eroded at the business end, you can usually bet on it that the point of inflection has been outside of the nozzle bore or that the bore

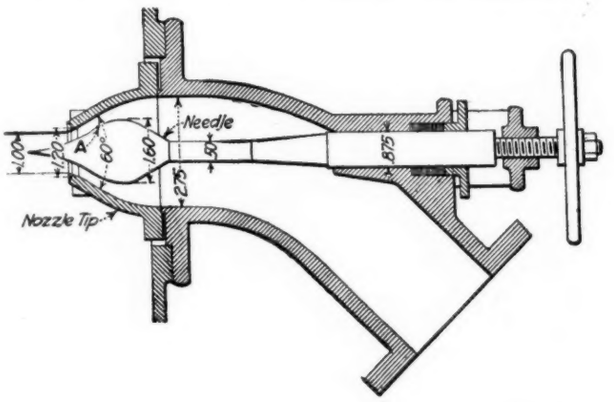


FIG. 2. SECTION THROUGH NEEDLE NOZZLE

has been worn large by sand and the needle worked its way through."

"I suppose that the handwheel mechanism that you show is something like that of a gate valve," Jimmy suggested.

"Yep, it can be used like that an' in lotsa other ways. For instance, you might cut teeth in the rim of the handwheel and work it with another gear from a distance, or you could connect the needle direct to the

governor lever as it is often done when pipe-line conditions and the rotating masses of the generator and wheel are heavy enough. This will be taken up more fully later on when we goes to the subject of governors and speed regulation."

Pop reached over to his coat and dragged out four long, black cigars which he distributed among the notables present and proceeded to light. Having engulfed about half of his, Jimmy could think much better.

"And now," snoozled Pop between his teeth and cigar, "we'll talk about the buckets (see Fig. 3). When you look at the thing, it seems so dern simple that you wonder why perfessors make so much mathematics over it; but when you come to make a strict analysis of the design, you'll find it's a pretty complicated thing, and the old sayin' is true that they's a direct proportion between the simplicity of the article an' the amount of brainwork needed to git it to that stage.

"Now about the material for makin' buckets. Cast iron is used for heads up to about 400 ft., an' bronze above that. When the water is acid at any head, they uses bronze with proper alloys for strength to suit the head. Small buckets are usually made of bronze or brass, 'cause the brass takes a thinner cast edge than iron will an' is easier to machine. When the water carries sand or grit, cast steel is gen'ly used, except in the case of real small buckets which would be made of very tough bronze. They was a guy which tried to git one of the high-class builders of the Pelton wheel to make 'em outa pressed steel, an' the idee ain't so dern bad at that. But it was canned 'cause they'd have to have a steel die for nearly every order, since most all of 'em is special, an' steel dies is worth near their weight in gold. He probably got his idee from seein' some turbine manufacturer make his runner vanes outa stovepipe plate an' saw that they could bend the plate to fit the form quite nicely when hot.

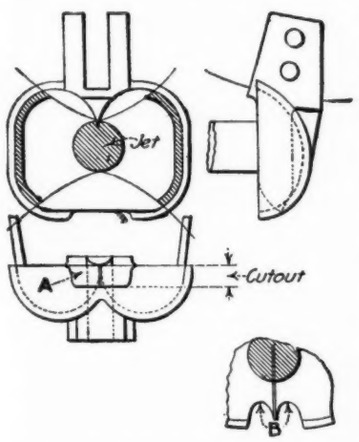


FIG. 3. SHAPE OF BUCKET BLADES AND CUTOUT

"Then they has made the wheels with the buckets cast solid with the wheel, a notable case bein' a wheel at the Colorado Fuel and Iron Co.'s works, where they has a wheel some 8 ft. in diameter, and a jet on it about 8 in. in diameter—a real high-head job. They is practical difficulties in the makin' of wheels like this 'cause in the pourin' of the mold the dirt in the iron or steel rises to the top, and then if one doesn't keep his fingers crossed, one side of the buckets will be spongy and dirty iron, helpin' erosion a great deal. If one bucket should be defective in that the iron didn't run well and fill the cores, the hull wheel would have to be scrapped, a big loss in money an' time. They has used other methods of casting the buckets—for instance, in twos and threes—but it costs high."

"What is that dingus you show in Fig. 4?" Jimmy was curious to know.

"That is a section through two buckets showin' about how the water discharges from the sides. In order that the water will enter the wheel properly, which means without shock, they has to cut away the front of the bucket as I shows at *A*, Fig. 3. That cutout must be deep enough to join on with the curvature in the inside of the buckets without any bumps or lumps, the shape of the bucket inside bein' sich that you can pass a section through it at any place and it must show a smooth an' gentle curve. One designer makes the cutout like I shows at *B*, which modern practice has discarded, 'cause it has been learned that they is water escapin' through that cranny at *B* in certain positions of the bucket as it turns around, all this bein' proved by means of instantaneous photographs. Now, Fig. 3 shows what is claimed to be the most perfect shape and form. Some will prob'ly come back an' say it ain't, and that the ellipsoidal form is more correct. One great objection to the last-named is that the dischargin' water from the sides will twist like the nodes in a vibratin' string or wire, causing interference with the precedin' bucket back, because the distance betweeen the nodes or twists is dependent on the head on the jet, an' you can't tell just when the nodes will strike agin the followin' bucket. You can prove this by placing a spoon in the stream running from a faucet showin' how the stream will twist."

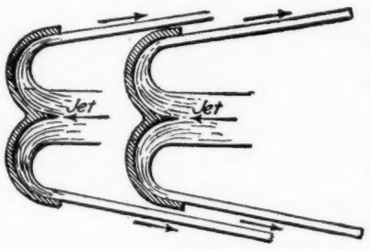


FIG. 4. SECTION THROUGH TWO BUCKETS

"Then I suppose that a bucket with straight sides all the way would be the right thing," Jimmy suggested.

"No, that has been tried for a good many years. That shape is showed in Fig. 5, showin' both the ellipsoidal and the Blue bucket, which is the name of the kind you last spoke about. With the Blue bucket the water has a tendency to bank up in the corners and havin' the same objection as on the ellipsoidal design. These bad points can be certainly avoided by havin' a very large bucket so that the thickness of the water sheet is small, but that increases the friction. In the Jackson style bucket, shown in Fig. 3, we has a combination of the best points of both the other styles, an' I might add that this shape has been thoroughly tested in over 1500 individual tests in Europe, so its cnaracteristics is purty well known. But don't git the idee the ellipsoidal bucket is a failure, 'cause it is far from that. In many cases it has shown very good efficiencies, but the Jackson style seems to show up better. Nowadays all the leadin' builders make the style shown at the left in Fig. 3, with but little change. Some will combine the shape of cutout at *A* with that at *B*, but them fellers is mostly of the German branch of design, an' hardly the up-to-date branch at that."

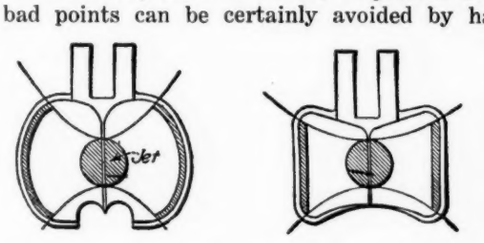


FIG. 5. ELLIPSOIDAL AND BLUE BUCKETS

Flywheel Explosion at Norwood, Ohio

About 7:45 p.m. on Sept. 15 the explosion of a gas engine flywheel in the municipal power plant at Norwood, Ohio, did considerable direct damage, and fire which resulted from the escaping gas practically ruined a great deal of the machinery. The estimated damage is $50,000, and this is considered to be on a pre-war price basis by some observers.

The unit causing the accident was a four-cylinder opposed gas engine, direct-connected to a 175-kw. 250-volt d.c. generator. At right angles to this engine was a four-valve single-cylinder steam engine direct-connected to a 200-kw. generator. There were also two tandem compound steam engines each direct-connected to a 100-kw. generator, as well as a 30-kw. motor-generator set.

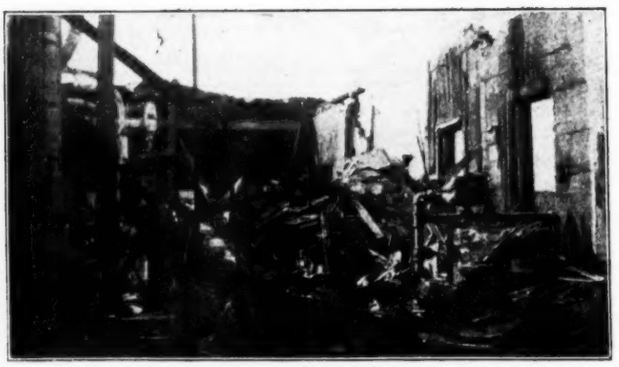


FIG. 1. THE WRECKED GAS ENGINE

According to the operator on duty, the No. 2 cylinder on the gas engine had been missing for some time, and he had been working on it up to a few minutes before the accident. It was apparently working better, and the operator started to go to another part of the plant when this cylinder seemed to backfire. This appears to have damaged the governor, for the engine at once began to speed up very rapidly. The operator was only a few feet away at the time, but the engine was picking up so rapidly that before he could go around the engine and shut off the gas, the speed was so high that he deemed it unsafe to try to reach the valve. His judgment seems to have saved his life, for before he could have reached the valve the flywheel let go. The explosion broke some of the gas connections, releasing a six-inch natural-gas main. The gas almost immediately took fire.

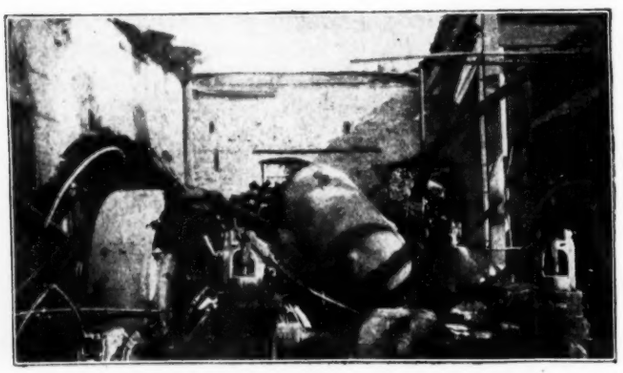


FIG. 2. THE GAS ENGINE AND GENERATOR

Pieces of the broken flywheel were thrown up through the roof and south of the power house to the B. & O. R.R. tracks, a distance of about 300 yards. Other pieces tore out a portion of the north wall and were found fully 100 yards away.

The four-valve steam engine, the plane of whose flywheel was east and west, also ran away, probably due to some wreckage of the building falling on the governor. This flywheel exploded, throwing one piece eastward over the top of the boiler room and nearly 100 yards away. Another piece was thrown westwardly about 200 yards and onto the roof of a four-story building. Fortunately, the roof was strong enough to support the shock with little damage. Meanwhile the two tandem compound engines were shut down by the operator.

A large part of the damage resulted from the fire. Street repairs were going on, and some of the material was piled over the street valve in the gas main. For this reason the attendants were unable to shut off the gas for some little time.

The gas engine that caused the trouble is apparently damaged beyond repair, it being, of course, in the hottest part of the fire. Except for its flywheel and a few minor parts, the four-valve engine appears to have suffered very little, either from the explosions or the fire.

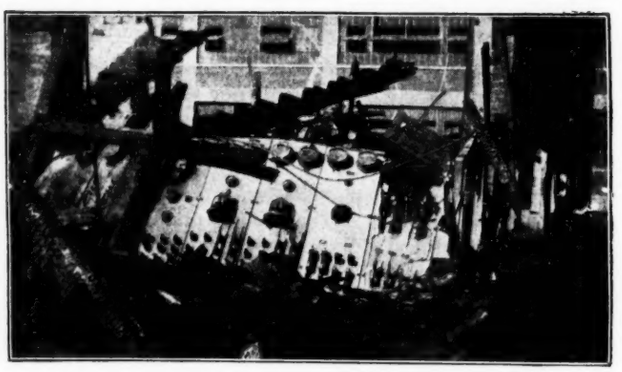


FIG. 3. THE WRECKED SWITCHBOARD

The tandem compound engines were only slightly damaged by fire. The four generators and the motor-generator set will be almost a total loss as their insulation was completely burned off. The switchboard was badly wrecked by the fire and by part of the roof falling on it. The damage to the steam piping does not appear to be very great. Considerable repairs will be required for the walls, and the roof, which was of frame construction, will have to be almost entirely rebuilt. Two a.c. units, the pumps and air compressors were damaged very little. The boiler room was untouched.

The operator's account of the events at the time of the accident, as given here, is verified by the oiler and seems to be borne out by what could be seen at the plant shortly after the accident.

Fig. 1 shows part of the gas engine under the pile of débris. Fig. 2, taken from the opposite direction, shows more of the gas engine with its generator. Fig. 3 shows the wrecked switchboard as well as some of the charred roof timbers.

Until repairs can be made Norwood is being supplied with water from the Cincinnati water works and with electric current from the Union Gas and Electric Company.

The Electrical Study Course—Power and Power Factor

The problem in the previous lesson is worked out and then the explanation is continued to show how to calculate power and power factor in a single-phase alternating-current circuit.

IN THE previous lesson the problem given was: 240 amperes flows through a coil of wire when connected across a 120-volt direct-current circuit, but when connected on 210-volts alternating current 300 amperes passes through the coil. Find the ohmic resistance R, impedance Z, reactance X in the coil, volts necessary to overcome the resistance and the reactance of the coil.

When the coil is connected to a direct-current circuit, the current flow is limited by the ohmic resistance only, consequently the resistance of the coil may be found by Ohm's law, $R = \frac{E}{I} = \frac{120}{240} = 0.5$ ohm.

When the coil is connected on an alternating-current circuit, the current is limited by the impedance Z of the circuit and, as explained in the previous lesson, $Z = \frac{E}{I}$, in this problem equals $\frac{210}{300} = 0.7$ ohm. The inductance ohms $X = \sqrt{Z^2 - R^2}$, in our problem $X = \sqrt{0.7^2 - 0.5^2} = 0.490$. The voltage E_R necessary to cause the current to flow through the ohmic resistance of the circuit is equal to the resistance in ohms times the current (Ohm's law is in direct current). That is $E_R = RI = 0.5 \times 300 = 150$ volts, and the voltage E_X necessary to overcome the inductance of the circuit is equal to the inductance in ohms times the current, or $E_X = XI = 0.49 \times 300 = 147$ volts. As was explained in the previous lesson, the inductance volts are 90 deg. out of phase with the volts causing the current to flow through the resistance of the circuit, and the relation may be shown in a right triangle as in Fig. 1. Then the volts $E = \sqrt{E^2_R + E^2_X} = \sqrt{150^2 + 147^2} = 210$ volts, which checks up with the volts assumed.

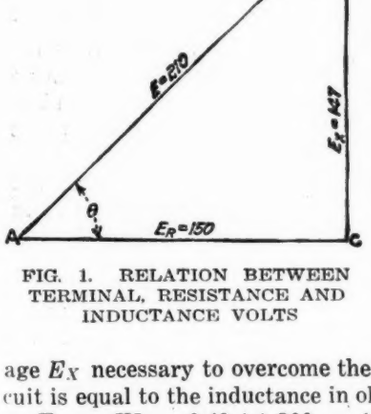


FIG. 1. RELATION BETWEEN TERMINAL, RESISTANCE AND INDUCTANCE VOLTS

The question now arises, What is the wattage equal to? Is it the voltmeter reading times the ammeter reading, Fig. 2; that is, $EI = 210 \times 300 = 63{,}000$? The answer is no, if there is inductance in the circuit as in this case. In the direct-current circuit the total power is equal to the square of the current in amperes times the resistance in ohms; that is, the watts $W = I^2R$. Then in the problem in question $W = 300 \times 300 \times 0.5 = 45{,}000$ watts. The value obtained by the product of the volts and amperes in an alternating-current circuit is called the apparent watts. We hereby have that the apparent watts equal 63,000, where the actual watts equal only 45,000. If we divide the apparent watts into the actual watts, we get a factor that is called the power factor of the circuit. The power factor in the case under consideration is $45{,}000 \div 63{,}000 = 0.714$.

The actual watts, which in our problem are 45,000, are what the wattmeter would indicate. The wattmeter reading is sometimes called the true watts. Since the power factor equals the actual watts divided by the apparent watts, it must also equal the wattmeter reading divided by (voltmeter reading $\times$ ammeter reading). From the preceding it is evident that the watts in a single-phase alternating-current circuit are equal to volts multiplied by amperes $\times$ power factor. Power factor is generally abbreviated *P.F.* Therefore the expression for watts in a single-phase alternating-current circuit is $W = EI \times P.F.$ Applying this in our problem, we have $W = 210 \times 300 \times 0.714 = 44982$ watts.

Power factor is frequently given in percentage. In such a case its value is multiplied by 100. Thus in the foregoing example the power factor could be given as $0.714 \times 100 = 71.4$ per cent. power factor. The apparent watts, instead of being called watts, are called volt-amperes, since they are the product of the volts and amperes. When large values are dealt in, a unit called the kilovolt-ampere is used, just as the kilowatt is used when the watts in a circuit reach a large value. There are 1000 watts in one kilowatt, and similarly there are 1000 volt-amperes in one kilovolt-ampere. The abbreviation for kilovolt-amperes is kv.-a., just as kw. is the abbreviation for kilowatts. The power factor is then equal to kilowatts divided by kilovolt-amperes; that is $P.F. = \frac{kw.}{kv.\text{-}a.}$

When there is no reactance in a circuit, but only resistance, the total alternating-current voltage is effective in causing a current to flow through the circuit. Thus in Fig. 3, where there is resistance only in the circuit, the current flows according to Ohm's law, and will be $I = \frac{E}{R} = \frac{225}{5} = 45$ amperes, as shown. The *true watts* $= I^2R = 45 \times 45 \times 5 = 10{,}125$ watts, and

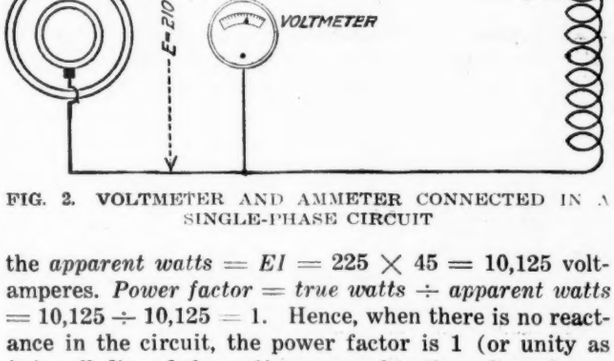


FIG. 2. VOLTMETER AND AMMETER CONNECTED IN A SINGLE-PHASE CIRCUIT

the *apparent watts* $= EI = 225 \times 45 = 10{,}125$ volt-amperes. *Power factor* $=$ *true watts* $\div$ *apparent watts* $= 10{,}125 \div 10{,}125 = 1$. Hence, when there is no reactance in the circuit, the power factor is 1 (or unity as it is called) and the watts are equal to the volt-amperes; but when there is reactance in the circuit, the power

factor is always less than one and the watts are less than the volt-amperes.

Usually, a wattmeter is connected into the circuit as in Fig. 4, in order to measure the actual power. In that event the power factor is most readily ascertained by dividing the wattmeter reading by the product of the voltmeter reading times the ammeter reading. Thus in Fig. 4 the value of W as read on the wattmeter is assumed to be 45,000 watts, the value of E as read on the voltmeter 210 volts, and the value of I as read on the ammeter 300 amperes. Consequently, we have $P.F. = \frac{W}{EI} = \frac{45{,}000}{210 \times 300} = 0.714$, as obtained previously in this discussion.

In an alternating-current circuit it is necessary to have an ammeter connected in the circuit whenever a wattmeter is used to indicate how much current is flowing through the wattmeter. The reading of the wattmeter itself is no indication of what current is flowing through it. If the inductance of the circuit is large in comparison with the resistance, the power factor will be low and the power transmitted in the system will be very small, and consequently the wattmeter will record only a small reading, whereas the current may be very large.

The current flowing in a single-phase circuit is equal to the wattmeter reading divided by the voltmeter reading times the power factor; in other words $I = \frac{W}{E \times P.F.}$

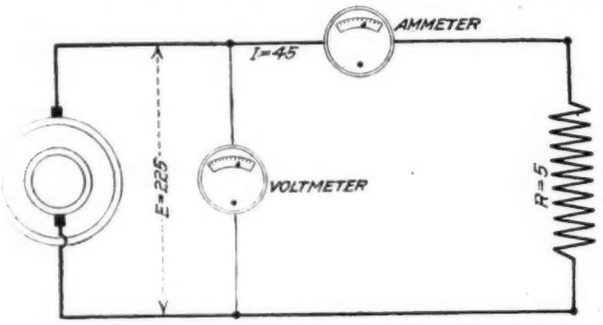


FIG. 3. REPRESENTING ALTERNATING-CURRENT CIRCUIT HAVING RESISTANCE ONLY

Now, if the wattmeter indicates a load of 45,000 watts when the power factor is 0.90 and the voltage 200, the current in the circuit would be $I = \frac{W}{E \times P.F.} = \frac{45{,}000}{200 \times 0.90} = 250$ amperes; if the power factor of the circuit is only 0.50 with the wattmeter reading 45,000 and the voltmeter reading 200, as before, then $I = \frac{45{,}000}{200 \times 0.50} = 450$ amperes. From the foregoing it is evident that the wattmeter reading and voltmeter reading are no indication of the current flowing in an alternating-current circuit, unless the power factor is unity. When the power factor is unity, the current is equal to the watts divided by volts, as in a direct-current circuit.

In Fig. 1, if we divide AC by AB we have $\frac{E}{E_R} = \frac{150}{210} = 0.714$ as a result. It will be noticed that this is the same value as was obtained for the power factor. It will also be noticed that $\frac{AC}{AB}$ is the cosine of the angle θ. Hence we find that the power factor and cosine have the same value. We therefore arrive at the conclusion that the power factor of a system is equal to the cosine of the angle that the total voltage makes with the voltage necessary to cause the current to flow through the resistance of the circuit. If we refer to a table of sines and cosines, as given in the lesson in the July 22 issue of *Power*, we find that cosine 0.714 corresponds to an angle of approximately 44.5 deg. The

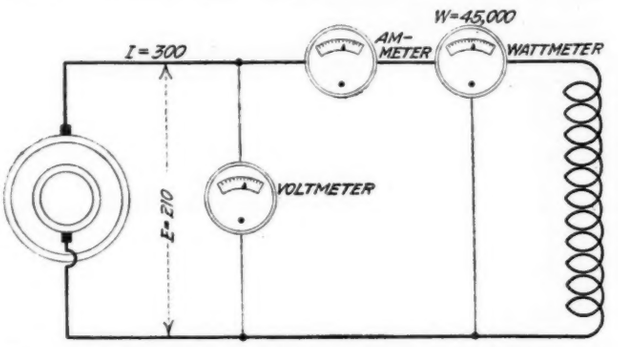


FIG. 4. VOLTMETER, AMMETER AND WATTMETER CONNECTED IN A SINGLE-PHASE CIRCUIT

angle formed between the resistance component of the voltage E_R and the total volts E is also the phase angle between the current and the voltage—in this case the angle of lag. This is the value indicated on a power-factor meter, and the power factor is frequently referred to as the cosine of the phase angle between the current and the voltage. Then to find the angle by which the current is out of step with the voltage, all that is necessary is to take the reading of the power-factor meter and refer to a table of sines and cosines and find the angle whose cosine corresponds to the power-factor meter's indication. Or we may take the voltmeter reading, ammeter reading and wattmeter reading as explained in the foregoing and calculate the power factor, and from this find the phase angle between the current and voltage. Thus, in the problem under consideration the angle of lag between the current and the voltage is 44.5, and since this is due to the inductance of the circuit, the current curve would be shown 44.5 deg. lagging from the voltage curve as in Fig. 5.

In a single-phase circuit the voltmeter reads 230, the ammeter 175 and the wattmeter 35 kw.; determine

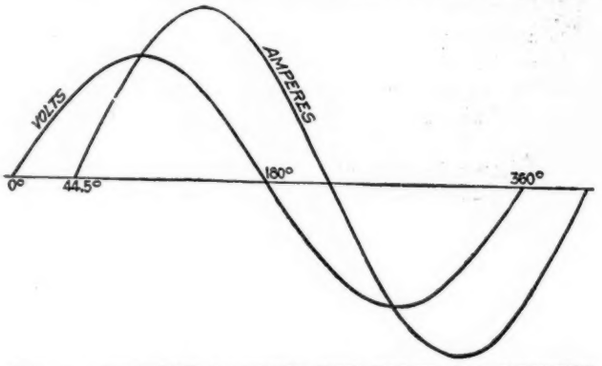


FIG. 5. CURRENT LAGGING THE VOLTS 44.5 DEGREES

the volt-amperes, kilovolt-amperes, power factor and the phase angle between the current and the voltage.

The power factor of a single-phase circuit is 0.80. The wattmeter reads 75 kw. when the voltage is 440. Find the ammeter reading, the volt-amperes, kilovolt-amperes and the phase angle between the voltage and current.

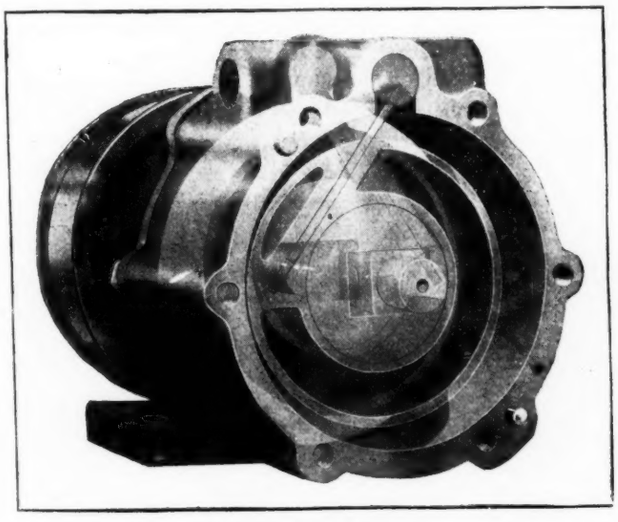
The Rollway Pump

The accompanying illustration shows the construction of the new "Rollway" pump, manufactured by the Michigan Machine Co., Detroit, Mich. The working parts consist of two rollers which rotate eccentrically in the pump chamber.

The pump chamber and rollers form a circle. The pump is divided in two by a steel disk. One roller operates on either side of the disk. The pump shaft is square. The opening in the rollers that fit the shaft is rectangular. A spring is inserted in one end of this rectangle between the square shaft and the roller. The rectangle is so placed on the shaft that it is slightly off center, bringing one side of the roller within a fraction of an inch of contacting with the side of the pump chamber. This contact continues except at a different point as the roller revolves. The rollers are so located on the shaft that they work opposite to each other; that is, when one is on one side of the chamber the other is at the other side.

A rocker that extends from the top of the pump down into the roller cuts off the flow from the discharge side of the pump so that the liquid cannot flow out through the intake. After the contacting point of the roller passes the intake of the pump, it creates a suction gradually filling up the chamber in back of the roller. When this point again reaches the top of the chamber, the liquid that it has taken in on the previous revolution passes out through the discharge while more is coming in at the intake side and so on. Operating alternately produces a steady flow without any pulsations.

The spring which operates between the roller and the shaft is an automatic relief and also prevents the pump from clogging. Should a chip stick in the pump



PHANTOM VIEW OF PUMP SHOWING ROTOR AND SPRING COVER REMOVED

chamber, the spring will compress and allow the roller to pass over it, and it will be washed out at the next revolution. It also operates when the stop-cock is shut.

Standard pumps are furnished with controlling spring to develop 25 lb. at 200 r.p.m. and 40 lb. pressure at 420 r.p.m., etc. Pumps can also be furnished with springs to develop either higher or lower pressures, or without springs where very high pressures are required.

This pump may be operated at speeds ranging from 100 to 600 r.p.m., upside-down or right-side-up, and at any point on a machine where its application is most convenient. Either side of the pump may be used for intake or outlet. Where it is necessary to maintain a constant flow in a given direction regardless of the rotation of the pulley, a pump equipped with reverse valves is furnished.

Handling Fires in Stored Coal

BY H. A. WARD

In the spring and summer of 1918 we stored 4000 tons of West Virginia nut and slack coal in an area about 140 ft. by 75 ft. This made a pile from 15 ft. to 20 ft. high. We endeavored to keep track of the

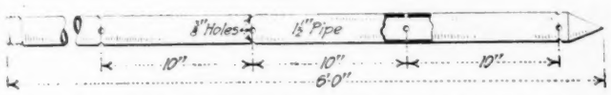


FIG. 1. THERMOMETER PIPE TO SINK IN COAL PILE

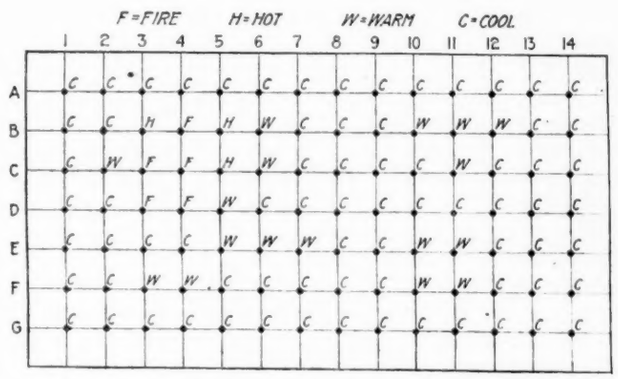


FIG. 2. TEMPERATURE-LOCATION CHART

temperature by occasionally going over the pile with ⅜-in. round rods sharpened at one end. By thrusting the rods down into the pile and allowing them to remain a minute or two and then withdrawing them we could tell by feeling the rods if the coal was heating and just how far the warmest spot was from the surface.

When we found a place which seemed to be getting too warm for safety, we would put down a 1-in. pipe and let a thermometer down into it so that we could determine if the temperature was still going up. The 1-in. pipe was prepared as follows: About 15 in. of one end was heated and flattened, thus closing the end. This flat portion was then given a twist like a drill or bit. By inserting this end into the coal and turning the pipe, at the same time exerting downward pressure, the pipe was easily driven through the pile.

Most of the coal was under a shed and in one small area it reached the roof of the shed. This interfered with the use of the ⅜-in. rod, and evidently this part of the pile was not carefully surveyed, as a fire developed about 15 ft. below the surface. To make sure that every part of the pile would be surveyed we put down 1-in. pipe as previously described, every ten feet.

We prepared ten pieces of sash chain the length of the pipes, placing rings in one end of each chain to prevent their being lost in the pipes. The ten chains were then let down into the pipes. By the time the

FIG. 3. PART OF PILE LEFT AFTER JUNE 1

last chain was placed, the first chain would become approximately the same temperature as the pipe. By letting the chain pass through the hand as it was withdrawn it was easy to tell the approximate temperature of the station. It was also easy to tell the relative temperature at the various depths at the station. The stations varied in temperature from cool to red hot. In a case of a warm station not in the fire area we usually found that the bottom of the pile was cold, and that the temperature increased, to a point about 8 to 6 ft. from the surface, where it was maximum. From this maximum point the temperature fell as the surface was approached. Every second or third day the entire pile was surveyed, using a cross-section sheet as in Fig. 2.

For a week previous to the starting of the fire the weather had been very hot. We found several stations remote from the fire heating to a dangerous point. As all available labor was employed in digging out the original fire, I decided to try water on the hot stations. Two pieces of 1½-in. pipe each 6 ft. long were prepared as follows: One end of one of the pieces was closed by drawing it to a sharp point. In circles starting at this closed point and spaced 10 in. centers I drilled four ⅜-in. holes 90 deg. apart. These perforations extended the length of the one piece of pipe. The second piece of pipe was fitted to couple to the first and to the fire hose. Then we sunk the perforated section into the coal at a hot station, coupled the second section to it and sunk them to the predetermined depth. After the water had been on 30 min. the pipe was moved to another point in the warm area, and so on until the area had been covered. This treatment brought the temperature down immediately. In some cases one application proved sufficient. In other cases the treatment had to be repeated from time to time. We still have on hand the part of the pile, Fig. 3, which was the most persistent in heating, and it has not had an application of water since the middle of November.

The surveys soon demonstrated that the fire was spreading faster than our force could follow it, and that it must be headed off or the entire pile would be affected. By carefully checking between the pipe stations which seemed to be just outside the affected area to see that the fire had not extended a finger in between, I established a line just outside the affected area. The pointed ⅜-in. rods were used for checking between stations. On 6-ft. centers along this line we put down 1-in. pipe prepared as already described, but with the addition of ¼-in. holes on circles 18-in. centers. This line of perforated pipes was connected with a common water supply pipe, the water kept on continually. The perforations above the surface of the coal were stopped with wooden plugs. This held the fire within the affected area. With this barrier established we sunk perforated 1-in. pipe into the heaviest of the fire and occasionally turned water into them. This checked the fire but did not put it out. It also did away with much of the smoke and gas which interfered with the digging out of the fire. Although the fire area extended over a space 50 by 40 ft., the fuel loss was comparatively slight. The coked areas were thin and only at the point where the fire originated did we find any indication of ashes.

Nearly all the literature I have found on the subject of heating and firing of stored coal has advised that as soon as the temperature of a station reaches 150 deg. F. the hot spot should be dug out. This is not always practical, as too many hot places may develop at the same time. Many of the articles advise that water seems to aggravate the trouble. I am inclined to believe that if a small quantity of water is used this may be true. The water leaving the hot coal flows through or under other parts of the pile not affected and thereby furnishes the initial heat to spread the trouble.

If a relatively large quantity of water is used, as in the case cited, the temperature of the water flowing through the coal approaches normal. For the same reason I believe that if water is used on the fire it should be in sufficient quantity, or the area treated should be sufficiently small to insure that the water flowing away through the pile should be of comparatively low temperature.

FIG. 4. ANOTHER VIEW OF THE PILE

EDITORIALS

Labor troubles have long delayed this issue of Power, but here it is. Moreover, no issues will be skipped and readers will receive all they subscribe for. We wish to thank our many friends for their support and patience during the suspension of publication.

America Is Yours Do Not Misuse It

THIS game of rising cost of living and upward, upward wages is like carrying water in a pail which leaks so badly that all the water is gone by the time you have reached the place where you want it. You may get a larger pail in the shape of more wages, but the resultant higher cost of things punches a larger hole in it.

The forms of the institutions of man forever change. Man, fundamentally, does not. The same instincts, emotions, and intellectual aspirations which actuated the Pharoahs and slaves of most ancient Egypt actuate the rich America.

Human nature is as enduring as the Rocky Mountains, more steadfast than a valley. It is simple in its make-up, complex in its reactions.

Self-preservation is its first law and the one to which all others are subordinate. A cockroach will fight if cornered.

All men are equal only in the sense that they are moved by the same basic instincts. Even these are not each equally possessed by all men, to say nothing of there being any equality of intellect, ambition, ingenuity, skill, ability in any direction. Men are as far from universal equality in these as their fingerprints are from being alike.

There is equality only before God.

Two of the great primary pursuits of man's life are food and shelter. He fights for these with weapons and laws.

Food and shelter are the reasons for agriculture and industry, whether the grinding of corn Indian fashion or in the Pillsbury mills.

Capital is an aggregation of economic goods used to produce other goods. It is human effort materialized. It is at one and the same time the product of effort and the tool of production.

The efforts that produce capital and make capital produce are manual, scientific and commercial. They are the tripod upon which modern industrial civilization rests. They are civilization's trinity, inseparable.

Regardless of who owns raw materials and capital or who controls labor, the necessities of life are not had unless both are at work to produce and distribute them.

Today the shelves of the world are bare. To replace what the war took from them everybody must work, not less but more.

If the reward (profit) of carrying on a business is too nearly all eaten up in taxes, wages and production costs, it isn't worth a man's while to continue it.

It would be silly to mention the foregoing simple facts if it were not that too much of the world seems to have forgotten them and to be running counter to them. Too many in the realms of both capital and labor seem to be trying to make a living, and more, by the methods of buccaneers.

The people are the consumers who pay all bills, who pay the costs and losses and who pay the ransoms. The railroads are an illuminating example. It won't do.

The people won't go on robbing themselves once they know it. They know it now. The railroad brotherhoods have flatly stated that further increases in wages are futile. It's the cost of living which must come down. It cannot come down if wages generally go up. It cannot come down if profits go up. It won't come down by strikes which curtail production and increase the shortage of the necessities of life. It will not be assisted downward if the intelligensia, the doctors, farmers, clerks, writers, editors, salesmen and other intermediate millions, maddened by the ever-increasing wage of labor, organize, demand and strike. Even now they are on the way. Organized labor has showed them how.

The way out is not by exploiting the United States of America.

When a minority of organized labor tries to do it, it is bolshevism pure and simple. The bolshevism of Lenine came by a coup by which 250,000 industrial workers seized absolute, autocratic control of 180,000,000 people. As conducted, it is the bloodiest, most despotic chapter in human history. It out-czars the Czar a thousand times.

The goal of all the urest today is a juster share in the returns of business by labor. The pendulum is swinging to the extreme, which is not surprising. But the business men and the working men of America can and will effect an adjustment without the bloody instrument of bolshevism. The man is shortsighted who does not see that this is so, whether he be a flaming radical or a stagnant, conservative capitalist.

For the sake of our stomachs, for the sake of the land which is ours, which we love, and which we saved from a despot's heel, let us go to work! Let us produce, produce! We must again show that democracy is safe for the world. America is yours. You cannot afford to misuse it.

State and City Elevator Laws

ONE of the problems confronting operating engineers is the keeping of the equipment in his charge in condition that will meet the various safety laws and regulations in operation in the different states. One of these codes, which is becoming of more importance each year, is the law regulating the construction and operation of elevators. Many of the large cities and a number of states have formulated and put in effect such laws. At the present time there is being prepared a national elevator code by the American Society of Mechanical Engineers working in conjunction with other interested bodies, including the United States

Bureau of Standards. When this code has been completed, there is every reason to believe that it will give impetus to the putting in force some form of elevator code in almost every state and large city.

To place before its readers some of the important elevator regulations of both states and cities, *Power* is going to publish excerpts from these laws. The first of these appears on page ??? in this issue and cover the regulations for New York State and City. Although the excerpts do not embrace the laws in all their different phases, especially as to new construction, they are complete enough in regard to existing installation to show those that are responsible for the upkeep and safety of elevator equipment if the regulations are being complied with and, if not, what must be done to meet the code.

Elevators in large cities have become of equal importance with electrical railway systems of transportation for handling the general public and employees of large industries. Therefore equal precaution should be taken in their operation. The reduction in the number of fatal accidents due to elevators where proper regulations are enforced is the one best argument for their promulgation. In the State of Pennsylvania in 1918 there were no fatal accidents from the operation of elevators, which cannot be said of states that have no elevator codes or of states that have regulation but are less exacting than the Pennsylvania code, which is accredited with being one of the best elevator laws in this country.

A large percentage of elevator accidents are caused either directly or indirectly from the use of shaft gates and doors that can be opened from the outside, or gates that are so low as to allow employees or others standing on the landings to look over into the shaft. The remedy in the former case is electric contacts on the doors and gates so that the cars cannot be started when the doors or gates are open, and in the latter case gates of sufficient height so that anyone standing on the landing cannot look over into the shaft. Regulations requiring proper shaft doors, car enclosures, next to proper safeties, will do more toward preventing accidents than any other requirement. Such installations are not expensive, especially on elevators that are electrically driven, and this type of machine forms a very large percentage of all those in use, consequently there is small reason why such requirement should not be part of all elevator codes. Where such a law is enforced, it has practically eliminated all fatal elevator accidents. Aside from the humanitarian and safety side, the prevention of one accident may many times pay for the installation of the necessary device to make the accident impossible.

Power-Plant Operating Record

The combination of the loose-leaf ledger form for log sheets and other statistics, reinforced by the card-index system of graphic records, is a scheme of power-plant bookkeeping that is coming more generally into use as its advantages become better known. All the records taken in the plant have a timely value and a few of them have a permanent value, but many of them after a year or so have little worth. Any possible value that the records may possess in any case will be only in proportion to the accessibility of their contents.

The records are made for the sole purpose of providing a future reference to the exact conditions existing at some particular time or to the results of routine or experimental accomplishments made under usual or extraordinary operating conditions. When this information is most needed, circumstances usually are such as to allow little time or inclination for searches for either the records or their contents. Printed forms are costly, as is the labor spent on inscribing the entries on them; so that if bunches of individual sheets tied in packages or enormous and awkward logbooks are to be stacked away in dusty storerooms, the investment made on them will be out of proportion to the value received.

Little of the data customarily collected, on switchboard log sheets, etc., is worth preserving. The bulk of the records made periodically over the whole day in the plant become useless after a time. An intelligent summary of them is of far greater value and can be inscribed on considerably less paper.

A summary of the hours idle, in reserve or operating, and the output for the day of each unit—boiler, turbine or generator—together with its load factor, its maximum, minimum and average loads and the details of its operation at those loads—such as its temperature, current, power factor, etc., if a generator; its vacuum, steam flow, condenser-water temperature, etc., if a turbine; its hours steaming, floating, banked and dead, coal consumption, etc., if a boiler—is of far greater value than all the itemized notations made periodically over the entire day. However, the periodic records have a timely value and are essential both as a check on the operation of the plant and as the means of providing the data for the permanent records.

The same thing applies to the group records made for the whole plant. Like summarizations may be made of the consumption of coal, water, oil, and all the lesser details of operation; and all the general information gathered for any one day may be summarized on one sheet. From these daily summaries are then made the weekly, monthly and yearly summaries. All the permanent record sheets may be then bound in attractive yearly or half-yearly volumes and constitute a library for the plant that is imposing as well as indispensable.

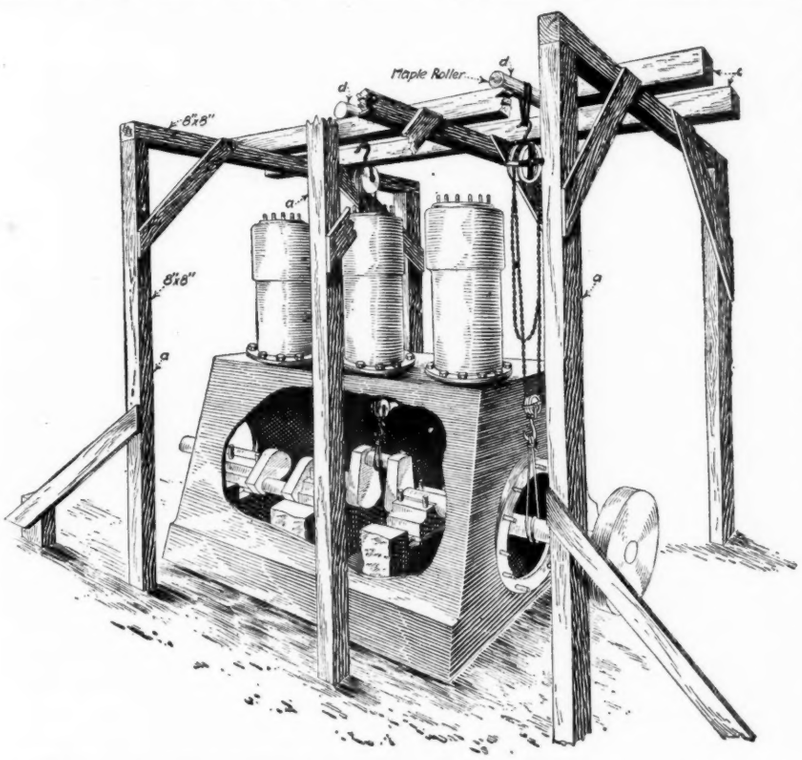
Reinforcing the volumes of written statistics, a card index is maintained. Yearly load curves are kept on the cards showing the weekly peaks of the station and the different classes of service supplied. Coal consumption, various plant costs, engine or turbine efficiency and other records of the plant are thus graphically portrayed on these cards. The cards are ruled in cross-section in a special form, so that one card form is adaptable to all requirements. They range in size from 6 x 8 in., to the standard letter size, according to the method used in filing them.

The trend toward efficiency of operation has been to isolate that information possessing only a timely worth and to conveniently assemble and preserve that found to be of permanent value. The old style daily load curve has lost much of its value. Logbooks are no longer the massive, awkward volumes of old, containing great sheets of figures over which were inscribed various colored curves representative of different phases of operation.

Correspondence

Removal of Diesel Crankshaft

Recently, it became necessary to remove the crankshaft of a three-cylinder vertical Diesel engine. This unit was provided with a box frame with circular flanges at each end, surrounding the shaft. The shaft had to be raised off the main bearings and moved longitudinally through the circular flange opening. Considering the diameter of the opening, which was 30 in., in relation to the extreme width of the crankshaft from pin to pin, 30½ in., the task was by no means an easy one. The job was made increasingly difficult by the inability to remove the bearing-cap studs. Furthermore, the engine had been moved outside the engine room, so that there was no trolley chain hoist to do the work. A frame of 8 x 8-in. oak timbers was erected, as shown in Fig. 1. At the tops of the vertical timbers *a*, ¾-in. holes were bored to a depth of 10 in. and threaded iron rods inserted. The three top cross-timbers *b* were bored and held fast by the bolts in *a*. Two 16-ft., 8 x 8-in. timbers *c* were spiked longitudinally on the cross-timbers.



FRAMEWORK AND POSITION OF THE BLOCKS USED FOR THE REMOVAL OF CRANKSHAFT

Two 6-in. maple rollers *d* were placed on the timbers *c*, and rope slings were passed around them and fastened to two 4-ton chain blocks. Since the shaft weighed eight tons, the blocks were amply strong.

The main-bearing caps were removed from all the bearings, while the entire end bearing was taken out in order to provide room for the removal of the crankshaft. The bearing wedges were not touched, and as the bearing was dowel-pinned against side shifting, the bearing could be replaced without realigning the shaft.

Rope slings were passed around the shaft and hooked to the blocks. The shaft was then lifted. Two workmen, using small bars, pinched the rollers along the timbers *c* until the block chains touched the sides of the top openings of the engine frame. The shaft was then blocked up and the rollers moved to a new position, whereupon the blocks were again fastened to the shaft and the endwise movement of the shaft continued.

The three sets of crankpin throws were of course 120 deg. apart, and this necessitated continual shifting of the shaft to allow the throws to pass the main-bearing studbolts.

At the beginning of the work various estimates as to the time required were secured from practical engineers. These estimates ran from four days to ten days with an expected cost ranging from $200 to $400. The actual time was surprisingly low. Six men were used for 15 hours in removing the frame doors and bearings and in erecting the framework. The time occupied in actually handling the shaft was just 5 hours. The cost was as follows:

Labor:	
Removal of doors and erection of frame (90 hours)	$45.00
Removal of crankshafts (30 hours)	15.00
Lumber:	
Seven 8 x 8-in. oak timbers 16 ft. long, eight 2 x 6-in. spruce planks 16 ft. long, 750 feet at $70 per M.	52.50
Total	$112.50

Since the timber was already on hand, this item is hardly chargeable to the job, and the actual cost was $60 with two or three dollars for spikes and bolts that were not charged.

E. E. SNOW.

San Pedro, Republica Dominicana.

Homemade Asbestos Gaskest

A cheap method of making a tight flange joint and one that will stay tight, is to use wet sheet asbestos $\frac{1}{16}$-in. thick. This can be used only when the flange is lying flat and the other half can be carefully lowered upon it, as wet sheet asbestos becomes so soft that it cannot be handled. The gasket must be cut to the proper size, then laid on the face of the flange and water applied. Joints made in this way 15 years ago are still tight.

One engineer made a gasket from the $\frac{1}{16}$-in. sheet asbestos with a covering of fine brass gauze on each side. This gasket could be made wet and used on joints in any position. Every joint made with such a gasket was a success.

JAMES ELLETHORN.

Kingston, Ont., Can.

Synchronizing Two Alternators When Driven by One Turbine

We have two 50-kv.-a. 220-volt three-phase 60-cycle generators, both direct-connected to one steam turbine through reducing gears. The shaft in the turbine became worn, and the engineer took it out and put in a new one. In doing so he must have shifted the gears so that when the couplings were bolted together the rotors were in some way displaced from their original position.

When the turbine was started and the fields excited, the generators' stator windings would get so hot in a few minutes that they had to be shut down. The generators were phased out and leads that were together run a motor in the same direction. I shifted the coupling of one generator one bolt hole and got the field magnets in the same position on both generators, which did away with the heating when the turbine was driving the generators, 1300 r.p.m. and the generators not excited. As soon as the voltage was raised to 220, the turbine slowed down to 1150 r.p.m., and an ammeter connected in one of the leads shows 75 amperes flowing between the generators. Both generators are excited from the same exciter, and the voltages of both are controlled from the same rheostat. A voltmeter shows four volts difference between the generators.

The generators run 1200 r.p.m. and have 6 poles and 72 coils, the latter connected parallel-star. Is there any way of telling how to mesh the gears so that the generators will be in phase at all times?

South Kaukauna, Wis. MARION PHILLIPS.

[This letter was submitted to K. A. Reed, who gives the following explanation.—Editor.]

In all probabilities Mr. Phillips has a unit composed of a high-speed turbine direct-connected to two alternating-current generators by means of a single pinion and two gears, as illustrated in Fig. 1. Assuming that this is true, the trouble experienced is due to the fact that when the engineer dismantled the unit, he failed to mark the pinion and gears, and when it was reassembled they had to be meshed by guess. The result is that the field poles have been moved from their original relative position and the machines are mechanically out of phase; consequently, there is a large circulating current between them at no load when they are connected in parallel and brought up to voltage.

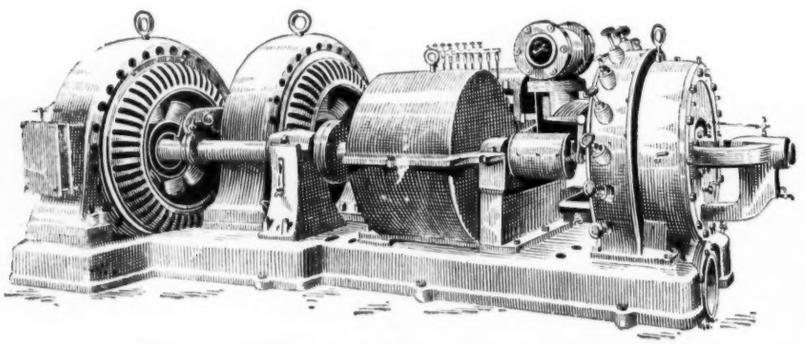


FIG. 1. TURBINE GEARED TO TWO ALTERNATORS

Shifting the field of one generator the space between coupling bolts is taking too large a step, since it moves the field poles of this machine one-quarter of a revolution forward or backward, when the generators are probably only a few slots out of phase. The reason for the speed dropping from 1300 r.p.m. with no excitation to 1150 r.p.m. at normal voltage of the machines is probably due to the load of 75 amperes which comes on as the voltage is brought up, and the turbine governor possibly needs some attention. In order to get proper operation out of this unit, it will be necessary to place the generators in exact synchronism mechanically, and this may be done in the following manner:

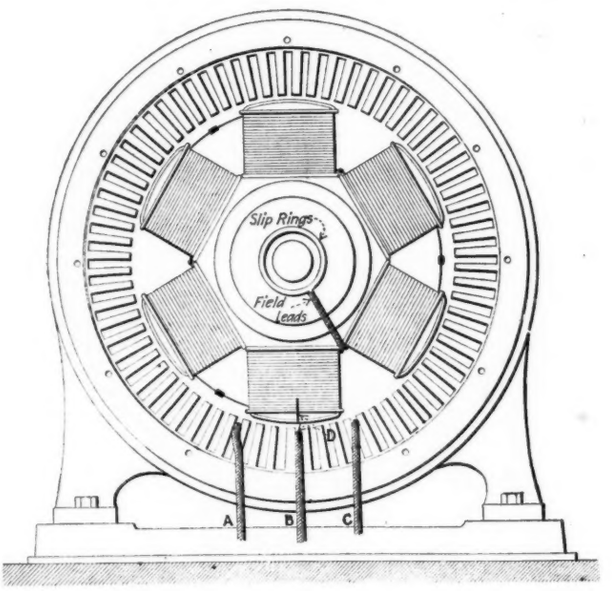


FIG. 2. DIAGRAM SHOWING RELATION BETWEEN POLE-PIECES AND PHASE LEADS

Turn the fields of the generators by hand until the center of the field coil connected to one of the collector rings, say the inside ring, of the left-hand machine comes exactly over a phase-coil lead slot, say phase *B*, as in Fig. 2. Now loosen the bearings of the right-hand machine and unmesh its gear from the turbine pinion. Turn the field of this machine without disturbing the position of the other machine until the field connected to its inside collector ring and the lead coil of phase *B* are in the same relative position as on the left-hand machine. Then mesh the gears and tighten up the bearings. In order to be able to again place the fields in the exact positions which they are now relative to the stator-phase coils, the position of the field poles over the phase *B* leads and the slots from which the leads come out should be marked with chalk, as at *D*, Fig. 2. The machines will now be synchronized as nearly as possible by guess. It may be found necessary, however, to reverse the leads from the exciter to the collector rings of one of the machines.

Bring the unit up to speed with the resistance in both exciter and generator field rheostats all turned in. With an ammeter in one of the generator leads close the switch that connects the machines in parallel and bring up their voltages. Observe the current indicated by the ammeter, and if it is abnormally high (over 100

amperes), shut down the unit and reverse the field leads to one pair of collector rings, as mentioned in the foregoing. The circulating current should now be very much reduced or practically eliminated. However, if an appreciable current still flows, the fields should be placed in exactly the same position as before by means of the chalk marks, and the right-hand gear unmeshed. Rotate this field about two slots either forward or backward, using the chalk mark as an indicator, for trial; remesh the gears and try again. If the current be-

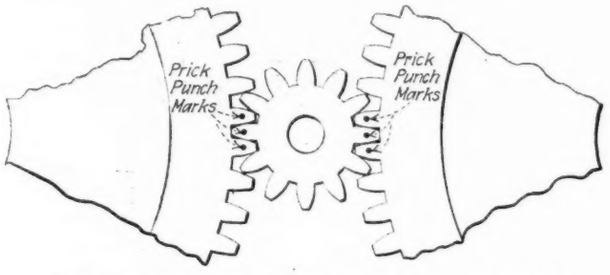


FIG. 3. HOW GEARS ARE MARKED AFTER BEING PROPERLY MESHED

tween the machines is less than before, it is obvious that the field was shifted in the correct direction, and it is only a question of shifting this field one or two slots at a time until the generators are properly synchronized mechanically. If the current is greater than before, the shifting was in the wrong direction and must be reversed.

After the proper meshing of the gears has been secured, the pinion and the gears should be center-punched as in Fig. 3, in order that the machine can be reassembled properly if dismantled at a later date. Somewhat better operation will be secured and the current between machines will be reduced by inserting the proper amount of permanent resistance in the field circuit of the generator whose voltage is four volts high to make its voltage the same as that of the other machine.

In answer to the last question in Mr. Phillips' letter, it should be noted that after the gears are properly meshed and the field leads connected to the collector rings correctly, the generators will be in phase at all times.

K. A. REED.

New York City.

Priming Centrifugal Pumps

Two reciprocating pumps originally supplied all the water required for house-service use and makeup in a plant at which I was employed, but upon enlarging the works two turbine-driven double-suction centrifugal pumps were installed. The centrifugal pumps are on a single suction line with a suction lift of 10 ft., working against a pressure in the house-service line of 60 lb., and each was rated at 350 gal. per min. The suction line for the pumps had a twin-strainer and float-valve fittings.

The pumps were primed by filling the casing and suction lines with water, supplied from the house service line, which was kept under pressure, and bleeding the air through a pet-cock on top of the casing.

This method sufficed until the foot valve became inoperative and would not hold water, and considerable trouble was experienced in picking up water when only the pump casing and short length of pipe to the strainer could be filled. It was thought that rubbish was caught in the valve and prevented it from seating properly and that in time it would clear itself. Therefore no inspection of the valve was made, owing to its arrangement in the intake tunnel and the delay and expense involved, but the valve did not clear itself. Having two surface condensers, one or the other of which was always in operation, we ran a 1-in. line from the pumps to each condenser, and now our priming troubles have practically disappeared.

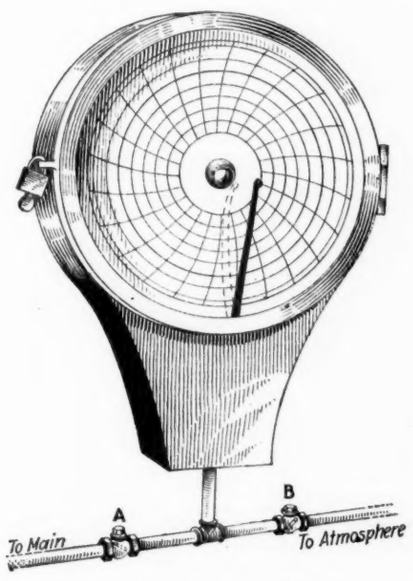
The water for seating the pump shafts in the stuffing-boxes was originally taken from the discharge side of the pump, below the check-valve, which means that when priming with the vacuum line no sealing water on this pump was available, so a connection was made above the check valve on the discharge line, which insures plenty of sealing water.

I might state that if the service-water pressure drops below 40 lb. a tank on the roof will feed into the line, and in case of a pump going out of service this tank will keep up a supply from 10 to 20 minutes, depending on the number of units in the service, etc., thus giving ample time to get another pump in operation.

Chicago, Ill. ARNOLD ERICKSON.

Check Valves in Recording Steam-Gage Piping

In looking over the Aug. 12 issue I read I. S. Chamberlain's letter on steam-gage connections. If the check valve at *A* closes to prevent the vacuum in the line from



ARRANGEMENT OF CHECK VALVES

forcing the pen hand too low, how does the pen work with a falling steam pressure? It would seem that an increase in pressure would be recorded more or less truly, but that a lowering of pressure would not permit the gage to record properly. Secondly, a column of water should be in the gage pipe at all times to protect it.

If air is drawn in the pipe at *B*, will not this cushion affect the working of the gage?

New York City. C. W. PETERS.

Why Does the Water Lift in a Boiler When the Safety Valve Blows?

In response to your editorial request in the issue of June 24, I submit the following:

If steam is being formed in a body of water more rapidly than it can separate from the water, then the volume of the water must expand by reason of the contained steam.

A well-built boiler is designed so that the maximum quantity of steam capable of being produced on its heating surfaces can be liberated from the water without undue ebullition. In such a boiler no severity of firing can cause the water to lift, but when the water is called upon to liberate, not only the steam coming from the heating surfaces, but also the large quantity of steam—of stored—energy that comes from the whole body of the water on a reduction of pressure, it can easily be seen why the water may lift when a safety valve blows. If the heating surfaces are not working hard and the quantity of water in the boiler at the time is not great, there is very little danger of its lifting. Some of us think that lifting occurs when the glass is full because the water level is close to the safety-valve nozzle. This is only part of the truth; the rest of it is that the larger body of water contains a great quantity of steam to be liberated for a given drop in pressure, bringing about the conditions of the opening statement.

Add to this the fact that the rising water is thrown to the center of the boiler by the arc of the shell or drum above the water level, thus causing it to creep up the curved shell to the safety-valve nozzle. From this it seems plain that the thing to be avoided is a too rapid lowering of pressure, making the capacity of the valve the important point rather than whether it be of large disk and low lift or small disk with high lift.

The best solution I know of is the use of two small valves rather than one big one. These are mounted on the branches of a common yoke and are set to pop about one pound apart. The lower set one will blow with a small capacity and a correspondingly slow reduction of pressure for all ordinary relief, and the higher set one operates only in case of emergency. This gives a rapid reduction in pressure through the operation of the combined valves only when such rapid reduction is needed.

Here in British Columbia it is against the law to put on a valve larger than 3 in., and where greater capacity is needed two valves are specified.

Vancouver, B. C., Canada. R. MANLY ORR.

I read with much interest the editorial on page 983 of the June 24 issue, "Why Does the Water in a Boiler Lift When the Safety Valve Blows?" It is true that though we cannot physically visualize the actual happenings in a closed vessel such as a boiler when the safety valve blows, we can try and mentally do so, and reason thereon in logical steps and thereby reach a conclusion as to what really does take place.

To my mind, the diminution of pressure immediately below the valve opening, coupled with the physical action of the steam as it rushes to the point of discharge, is responsible for the carrying over of the water in the following manner: The diminution of the pressure takes place almost instantly over a certain portion of the cubical contents of the boiler. This area of reduced pressure reaches to and below the water line of the boiler, and because of that reduced pressure the volume of water thus affected immediately flashes into steam (necessarily of a very wet nature because there is a great amount of entrained water in it). The action of the increased amount of water flashing into steam leaves more or less of a hollow in the general water level, and the water then remaining in the boiler sets up another counter-current in its endeavor to overcome the unstable condition thus caused, and the resultant effect is somewhat of a wave-crest action, which heads immediately under the valve opening, thus raising the water level at this point somewhat higher than the other general water level in the boiler. In the meantime, however, the rush of steam toward the valve opening has become more or less of a swirl (as the water running out of any container will tend to do if the flow of water is from all sides toward the point of discharge), and the physical action of the steam, rushing in this swirling manner around and upward immediately over the wave crest, takes up a certain amount of water; which water is half water and half steam, the ebullition having become so great at this point from the reduced pressure, and carries it over or out of the valve. When this slug of water entrained in the steam strikes the constricted area of the valve opening, there is more or less of a damming up of the steam and therefore a reaction, or reverse pressure wave, that carries back to the water level and causes, first, a greater depression of the water level, which in turn causes a recurrence of the wave or cresting effect, and the continued flow of steam carries over more and more of the water until finally it appears almost as if it were a solid stream of water.

The wave action is somewhat similar to that which can be produced in an open vessel by the rythmic action of a paddle working perpendicularly to the surface of the water. I have seen this wave action so great that it would cause the water to rise as high as 12 in. above the normal water level where there had been very little effort exerted, and had there been the scouring and carrying effect of a heavy current of air or steam, there is little doubt that the vessel would have been entirely emptied, though I do not believe that the carrying over of water from a blowing safety valve could empty a boiler. McKEAN MAFFITT.

Wilmington, N. C.

Regarding lifting water when the safety valve blows, why not connect the safety valve to a dry pipe extended along the inside of the boiler, close to the plates, and draw steam from the entire length of the boiler when the safety valve opens, instead of from one point directly under the valve, as is usually the case.

Another condition that will help in preventing the water lifting is to keep the water level at or slightly below the column second gage-cock. Some water tenders keep the water level up to the top try-cock, or within two or three inches in the top of the gage-glass, although they know that the area of the surface of the water inside the boiler is thereby reduced, and they *should* know that the greater the area of the water surface the easier a large volume of steam will be given off, thus reducing the chance of priming or lifting of the water. JAMES E. NOBLE.

Kingston, Ont., Canada.

Inquiries of General Interest

Cutting Pipe Threads on a Lathe—When cutting pipe threads on a lathe with taper attachment, should the lathe tool be set square with the taper or square with the lathe center? F. A. K.

The cutting tool carried by the taper attachment should be set square with the lathe center; that is to say, the tool is ground to cut a V-thread of 60 deg. and so set that each side of the finished thread will make an angle of 60 deg. with the lathe center, or what would be the same thing, 30 deg. each side of a line square with the lathe center.

Moisture in Transformer Oil—What is a simple method of testing transformer oil for moisture? W. E. S.

Anhydrous copper sulphate when placed in transformer oil will give a bluish tint if moisture is present in the oil. If some small pieces of hot iron or nails are dropped into a sample of the oil the presence of moisture will be indicated by the hissing sound produced. Before applying either one of these tests by the uninitiated, it will be advisable to make the tests on samples that are known to contain moisture and others that are known to be "dry," so as to become familiar with the reactions under both conditions.

Front of Engine—What is the front of a horizontal engine? A. C. U.

The front is the face or part opposite to the cylinder end of the engine. The cylinder end is commonly called the "back" end. These terms are not self-explanatory, and "cylinder end" and "crank end" are better. The only excuse for "front" and "back" end would appear to be that they are consistent with calling the stroke of piston from the outboard end of the cylinder the "forward" stroke, in agreement with the usual direction of the power stroke of a single-acting engine, and for the stroke to be "forward" it would have to be toward the "front."

Effects of Low Power Factor—Will an alternating-current generator be affected by poor power factor, when the generator is supplying power directly to lightly loaded induction motors, the same as when the load is supplied through transformers? E. G. H.

It will not make any difference whether the generator supplies the power directly to the motors or through transformers to the motors, the kilowatt capacity of the generator will be reduced in either case by the low power factor of the motors. However, the power factor of the system will be lower where the transformers are used, on account of the power factor of the transformer being less than unity even under full load.

Convex and Concave Bumped Heads—How are bumped heads of steel plate named with respect to the manner in which they are set in drums, and what is their relative strength with respect to the side receiving pressure? F. A.

Bumped or dished heads are called convex or concave according to the form of the side that is presented outside of the drum or other vessel in which they are used. In good practice the concave heads of drums or other pressure vessels that have the pressure on the convex side of the heads are allowed a maximum working pressure equal to 60 per cent. of that allowed for dished heads of the same dimensions with the pressure on the concave side.

Right-Hand and Left-Hand Shoveling—Is a right-hand shoveler one who supports the weight with the right hand, or with the left hand? G. A.

A right-hand shoveler supports the weight on the scoop or blade by holding up the tang or the neck of the shovel handle with the left hand. He grasps the handle farther away from the tang, usually at or near the free end of the handle, with the right hand, and the directon of his toss is from his right hand toward his left hand. When the positions of his hands and direction of his toss are the reverse, the method is called left-hand shoveling. Each method is named to accord with the manner that is more natural to a right-handed or to a left-handed person in the exertion of his strength to fill the shovel and perform the toss.

Gain from Heating Feed Water—For generation of steam at 90 lb. gage, what is the percentage gain when boiler-feed water is heated from 50 deg. F. to 210 deg. F.? R. L.

A pound of dry saturated steam at 90 lb. gage, or 105 lb. absolute, contains 1187.0 B.t.u. above 32 deg. F., and when the feed water is at the temperature of 50 deg. F., or (50 — 32) = 18 deg. above 32 deg. F., for conversion into steam at the stated pressure each pound must receive 1187.2 — 18 = 1169.2 B.t.u. When the feed water is at the temperature of 210 deg. F., each pound of feed water evaporated requires 210 — 50 = 160 B.t.u. less, or only (1169.2 — 160) ÷ 1169.2 × 100 = 86.3 per cent. as much heat for conversion into steam, and the gain would be 13.7 per cent.

Synchronous Motor for Power-Factor Correction—When synchronous motors are used for power-factor correction, what horsepower capacity should be used per 100-hp. capacity of induction motors? The sizes of the induction motors range from 10 to 30 hp., and the system has about 200-hp. capacity. E. G. H.

There is no specified number of synchronous-motor horsepower capacity required for power-factor correction per 100 hp. of induction motors installed. The synchronous-motor capacity required will depend upon how much of the mechanical load is to be driven by this motor, the value of the power factor before correction and the amount of the correction. If the induction motors are lightly loaded, the power factor will be low and a greater kilovolt-ampere capacity will be required in the synchronous motor to correct the power factor than where the induction motors are operating near their rated capacity and the power factor is at a comparatively high value.

Physical Properties of Materials—What is meant by the terms "elastic limit," "modulus of elasticity," "permanent set," "ultimate strength," "percentage of elongation" and "reduction of cross-section" with reference to materials of construction? R. N. B.

The elastic limit is a more or less definite value of the unit of stress beyond which, as the stress is increased, there is a greater relative deformation than the increase of stress. "Permanent set" is used to represent the lasting deformations produced by stresses greater than the elastic limit. "Modulus of elasticity" is a term used to express the ratio of the unit stress to the deformation per unit length within the elastic limit. The total stress under which a body fails is called its "ultimate strength." The ratio of the total elongation of the specimen to its original length is called the "percentage of elongation." For calculations of percentages of elongation measurements are usually taken between marks originally 8 inches apart. "Reduction of cross-section" is usually expressed as a ratio of the smallest cross-sectional area after rupture to the original cross-sectional area.

Excerpts from Elevator Laws of New York State and New York City

By EDWARD A. SMITH
Mechanical Engineer, Otis Elevator Co., New York, N. Y.

EXCERPTS from rules of New York State Factory Laws for power-driven passenger, freight, sidewalk and handpower elevators, effective Apr. 25, 1915, in factory buildings only. These rules do not apply to New York City.

Load: Passenger—75 lb. per sq.ft. floor area; Freight—50 lb. per sq.ft. floor area, lowering where more than 100 persons are employed.

Runby at top: Passenger and freight—18 in. minimum, 100 f.p.m. or less, between the top of crosshead and underside of grating; 2 ft. 0 in., over 100 f.p.m. and inc. 150; 2 ft. 6 in., over 150 f.p.m. and inc. 200; 3 ft. 0 in., over 200 f.p.m. and inc. 250; 3 ft. 6 in., over 250 f.p.m. and inc. 300; 4 ft. 0 in., over 300 f.p.m. and inc. 350; 4 ft. 6 in., over 350 f.p.m. and inc. 400; 5. ft. max., over 400 f.p.m. Same for counterweight, except with car on bumpers, 3 ft. maximum runby required. May be modified where long stroke bumpers are used with shaft slow-down.

Pit: Passenger, Freight and Sidewalk—6 in. minimum 50 f.p.m. or less between underside of car sling and pit: 12 in., over 50 f.p.m. and inc. 100 f.p.m.; 18 in., over 100 f.p.m. and inc. 150 f.p.m.; 2 ft. 0 in., over 150 f.p.m. and inc. 200 f.p.m.; 2 ft. 6 in., over 200 f.p.m. and inc. 250 f.p.m.: 3 in. max., over 250 f.p.m.

Guides: Passenger, Freight and Sidewalk—Steel or wood guides permitted.

Safeties and Governor: Passenger and Freight—Safety devices approved by commission under platform with governor to trip at 200 ft. for car speed 150 ft. per min. Greater car speeds of 40 per cent. in excess. No safety required on plunger elevators. Sidewalk, none required for rise of 30 ft. or under.

Car Enclosure Platform: Passenger—Substantial enclosure all sides except entrances. Emergency exit in top of car. Emergency exit may be in side of car, where two or more cars are in same shaft. If grill enclosure is used, 1½ in. spaced 1-in. straight bars. Folding gates not required if distance between car and hatch enclosure or door does not exceed 3 in. Contacts required on gates except one adjacent to operator. Platforms or enclosure not fireproofed. Cars to be lighted. Freight—Substantial enclosure 5 ft. 6 in. high. Slats may be used spaced to prevent hand or foot passing through. Solid over counterweight. Top of car No. 8 wire 1½-in. mesh, not to within 8 in. of hatchway at entrance sides unless car gate is provided. Sections may swing up. Platforms and enclosures are not required to be fireproofed. Car to be lighted.

Control: Passenger, Freight and Sidewalk—Car switch, lever or other controlling device to be located near most-used car opening. Where handrope or other controlling device is outside car, opening in car permitted.

Gates: Passenger and Freight—In new buildings shafts are required to be fireproofed. Gates not permitted, except with self-closing swinging doors. Then they are required. In existing buildings gates permitted in non-fireproof hatch, to be self-closing or manually operated. If manually operated, must have contacts. All gates 5 ft. 6 in. high with 10-in. under-clearance, with 2 in. between bars and to resist 150 lb. at center. Gates more than 12 in. from sill, 3 ft. 6 in. high not permitted for passenger elevators.

Gates: Freight only—Gates more than 12 in. from sill 3 ft. 6 in. high with 10 in. under-clearance if car is provided with telltale chains 4 ft. long, 6 in. apart, 2 in. from front of car. Telltale chains not required if automatic trap doors are used. If above conditions are impractical, commissioner will grant modification. Flexible-type gate permitted. Sidewalk—Same as for freight except there will be no gate at sidewalk level.

Ropes: Passenger and Freight—Not less than two ropes to car and counterweight. One full turn required on drum machines. Passenger safety factor, 8; freight safety factor, 6. No regulation for governor ropes. Sidewalk, ropes or chains permitted. Safety factor, 6.

Bumpers—Passenger and Freight—Springs under car

Grating: Passenger and Freight: Substantial grating to sustain 500 lb. required under overhead sheaves and other spaces not otherwise protected. For large elevators partial grating with hand rail and toe guard accepted. Wooden platforms or reinforced-concrete slabs permitted.

Counterweight Screens: Passenger, Freight and Sidewalk—Bottom screen, 5 ft. high. Bottom of screen, 18 in. above pit. For drum machines only, top screen 8 ft. long below beams. No. 16 gage iron or steel plates or other material of equal strength. In existing elevators if impossible to install screens between car and counterweight, use four telltale chains 4 ft. long on bottom of counterweight. Upper screens not required on traction or plunger elevators.

Stop Motion and Shaft Limits: Passenger, Freight and Sidewalk—Required on machine and in hatchway. No machine limits required on traction machines. Stop balls on handrope or chain will be considered as a hatchway limit.

Interlocks: Passenger—Electric contacts with emergency cutout in car or other device approved by commissioner. Required on swinging doors. Manually operated Peelle doors must have contacts with cutout in car. Electromechanical interlocks with emergency cutout in car and releases at floors will be accepted. Freight—Same as passenger. Vertical sliding, manual operated doors require contacts.

Emergency Switches: Passenger and Freight—None required except as noted in interlocks.

Brakes: Passenger, Freight and Sidewalk—No regulation. Electric, mechanical or electro-mechanical permitted.

Rope Locks: Passenger—No regulation. Freight—Required if car has no regular attendant. Sidewalk—No regulation.

Hatchway Enclosure: Passenger—Existing hoistways, enclosure to extend from floor to ceiling on door sides of hatchway. Door openings to have gates or doors to protect opening. On all other sides enclosure 6 ft. high. Enclosure to be walls, windows, screens or partitions. If grill is used, 1½ in. spaced 1 in. straight bars. Where trap doors are used, railing or solid enclosure 3 ft. 6 in. high, 12 in. from hatchway. Underside of sills to be beveled 60 deg. from horizontal. Freight and Sidewalk—Existing hoistways or hoistways reconstructed in old buildings, enclosures not less than 6 ft. on all sides except at openings where gates or doors are to be provided. Underside of sills to be beveled 60 deg. from horizontal. Future installations same as passenger.

Hatchway Doors: Passenger — In future buildings must have fireproof doors (see Labor Law 79—A-6). In existing buildings built prior to Oct. 1, 1913, sliding doors or gates to be full automatic or manually operated or self-closing or equipped with interlocking devices. If manually operated, doors to have key from outside. Peelle doors to have electric contacts. Swinging doors to be manually operated or self-closing. Manually operated doors to be provided with electric contacts and with emergency cutout in car or other approved device. Keys to open doors from outside to be furnished. Freight—In existing buildings built prior to Oct. 1, 1913, vertical or horizontal sliding doors may remain if high and strong enough for particular requirements where they are used. In future buildings same as passenger. Vertical sliding doors shall be self-closing or manually operated. If manually operated, electric contacts required or other device that will insure that doors are closed before car starts. Swinging doors, same as for passenger. Sidewalk—Same as for freight elevators.

Trapdoors: Passenger—Not permitted. Freight—Permitted only in buildings erected prior to Oct. 1, 1913, for open hatchways, with railing and semiautomatic gates 3 ft. 6 in. high placed 12 in. from hatch line. Doors to furnish a substantial floor covering when closed.

Motor-Room Enclosure: Passenger, Freight and Sidewalk—No regulation. Should be furnished in fireproof buildings in accordance with Labor Law 79—A-6 and 79—F-5.

Carriage Hoists: Future four corner pick-up power-driven carriage-type elevators not permitted.

Handpower Elevators: Maximum rise 75 ft. Wood or steel guides, broken-rope spring-operated safeties permitted. Car enclosure 5 ft. 6 in. high (no top required). If hatchway is enclosed floor to ceiling, no car enclosure required. On handpower sidewalk elevator, no car enclosure required. Hatch enclosure and semiautomatic gates required.

Operator: Required on all passenger elevators, competent operator 18 years old or over, except for push-button elevators.

Exit Facilities: In future installations no elevator to descend in passageways.

Elevators of New York City

Excerpts from elevator laws of New York City for power-driven passenger, freight and sidewalk elevators, except Department of Docks—(no regulation)—U. S. Government. Effective Aug. 26, 1918. Amended May 13, 1919. Effective June 9, 1919.

Load: Passenger—75 lb. per sq.ft. inside area. Capacity plate with suitable lettering required. Freight and Sidewalk—50 lb. per sq.ft., not exceeding 100 sq.ft. inside area. No regulation above 100 sq.ft. inside area.

Speed: Passenger, Freight and Sidewalk—Shall not exceed 700 ft. per minute.

Current: Passenger, Freight and Sidewalk — Reverse-phase relay required on all future polyphase installations. No other regulation.

Runby at

Top: Passenger and Freight—Not exceeding 100 f.p.m., 2 ft.; not exceeding 350 f.p.m., 3 ft.; above 350 f.p.m., 5 ft.

Pit: Passenger and Freight—Between lowest floor saddle and bottom of pit—not exceeding 250 f.p.m., 4 ft.; not exceeding 400 f.p.m., 5 ft.; above 400 f.p.m., 6 ft. Must be at least 2 ft. between underside of car platform, when on bumpers compressed, and bottom of pit. Pits must not be used for any purpose except elevator apparatus. Sidewalk, between bottom of pit and underside of platform, 6 inches.

Guides: Passenger, Freight and Sidewalk—Steel tongue and grooved or dowelled with wrought or cast iron brackets.

Safeties and Governor: Passenger—Over 100 f.p.m. toggle clamp safeties (gradual operating); 100 f.p.m. or under, instantaneous or roll-type safeties. No safety required for 15 ft. rise or under. Governor to trip at 40 per cent. above rated speed. Maximum tripping 850 f.p.m., minimum 150 f.p.m. Car-locking device required for safe-lifting elevators. Freight—Same as passenger. Existing freight, rise 5 stories or less, safety required but no governor required. Existing freight elevators with crosshead safeties can remain by furnishing governor. Sidewalk—None required on 35-ft. rise or under.

Car Enclosed and Platforms: Passenger—Existing and future installations, substantial enclosure, wood or metal, sides and top. On future installations if grill 1½ in. space, if bars 1 in. space. If space between car and counterweight is less than 2 in., enclosure to be solid over counterweight, or enclosure to be covered with ½-in. wire mesh, No. 16 gage, 6 ft. 6 in. high. In existing factory buildings wire mesh required on sides of car if in excess of above spacing. Folding gates or doors at each entrance (with contact and emergency cutout in car in rear of operator—future elevators only). Emergency exits—In future installations in top of car, 400 sq.in. in area, least dimension 16 in. Side emergency exits required in addition if two elevators in same hatch and vertical distance between any adjacent door openings exceeds 30 ft. In existing installations, emergency exit same as for future installations except in impractical conditions, Superintendent of Buildings will waive emergency exit provided egress can be had from floor openings or adjacent car. In future installations no auxiliary freight compartment allowed. Existing compartments must have gate with contacts. Cars to be lighted. Freight—Enclosures on freight cars not required except over counterweight unless in factory building. Underside of all platforms must be fireproofed. In existing and future factory buildings, enclosure on all sides not used for loading with substantial construction 5 ft. 6 in. high or to crosshead if less. If open construction is used, 1 in. space between members. Top of car to be No. 8 gage wire, 1½-in. mesh; to have self-closing hinged section at entrance 8 to 12 in. from sill (except where car gates are provided). Large hinged section permitted for handling long material. Gates are not required on freight elevators. If car has more than one opening and space between car and shaft exceeds 5 in., it is customary to furnish gate without contact at opening away from operator. In future installations no auxiliary freight compartments allowed. Existing compartments must have gates and contacts. Cars to be lighted.

Car Enclosures and Platforms: Sidewalk—Opening not more than 5 ft. from building line or more than one-twelfth width of street. Opening not more than 6 ft. long, parallel to building, without special permission from Highway Department. Platform not to exceed 50 sq.ft. Bow iron 6 ft. high permitted; if higher, special permission from Highway Department. No enclosure or gates required. Fireproofing underside of platform not required.

Gates: Passenger—In existing or future installations horizontal or vertical manually operated gates permitted (except push-button elevator) locked on shaft side, where elevator is surrounded by fireproof stair wall. Vertical-sliding gates to be 5 ft. 6 in. high, wood or metal, 2 in. between bars. 10 in. under clearance except at top and bottom floors may be more to give required head room. Existing shafts with trapdoors require gates. In factory buildings, existing and future installations, semiautomatic vertical-sliding gates to be furnished with swinging doors or doors with contacts or with interlocks. Freight—In existing and future installations in factory buildings only, vertical, semiautomatic gates, wood or metal 5 ft. 6 in. high, 2 in. between bars, to be used where swinging doors are used, or doors with electric contacts or interlocks. Existing shafts with trapdoors require gates. Sidewalk—Same as freight if there are intermediate floors.

Equalizers: Passenger and Freight—Permitted for overhead machines for car and counterweight.

Grating: Passenger and Freight—Required over future shafts under sheaves. Grating to sustain 75 lb. per sq.ft. Members spaced not more than 1½ in. apart. If machine is overhead, grating to be placed on top of machine beams. Deflecting or secondary sheaves and sheaves on sidewalk construction for passenger elevators to have grating under and on all open sides. Grating may extend over part of shaft 2 ft. 6 in. beyond bedplate or any machinery; to have screened railing 3 ft. high. Concrete slab permitted in lieu of grating. Trapdoor permitted in grating where other suitable access cannot be had. If penthouse door is more than 4 ft. above grating or roof, ladder required.

Counterweight Screens: Passenger and Freight—Existing and future installations, at top of shaft, length of counterweight, for drum machines only and where counterweight is in same shaft as car. Iron or steel No. 16 U. S. gage. Bottom screen 5 ft. high; bottom 18 in. above pit. Not required with counterbalance chains or ropes. In existing installations space between car and counterweight 1½ in. or less, no top or bottom screen required, but furnish 4 telltale chains on bottom of counterweight 5 ft. long, not over 6-in. centers from rail to rail.

Stop Motions and Shaft Limits: Passenger, Freight and Sidewalk—In future installations limit switches required on car or in shaft and on machines, on drum machines; shaft or car, traction machine; stop balls on rope hydraulic machines 150 f.p.m. or under, over 150 f.p.m. machines, for lever or crank operated hydraulic limits on machine.

Stop balls on rope or chain arranged to stop machine at terminal landings accepted by Building Department as shaft limit for sidewalk elevator, speed under 75 f.p.m. also machine limits required if drum.

Interlocks: Passenger and Freight—Required in existing and future installations in factory buildings only, either electric contacts to be used or swinging doors with emergency release in car or semiautomatic gates to be furnished. (See paragraph on gates.)

On all push-button elevators, standard push-button interlocks required. (Either No. 3 door lock or Wells-Van Alstyne for sliding doors.) Release for push-button elevators on landing side at all floors with key (except private house); release at lower landing only. Other mechanical or electro-mechanical interlocks permitted but not required. If mechanical interlocks are used, release must be provided outside shaft doors at each floor. (Ruling, Building Department, 10-21-18.) Sidewalk—No regulation unless rise more than one floor, then same as passenger and freight.

Emergency Switches: Passenger and Freight — Slack-cable device for drum machines only. Emergency switch in car. Emergency release for contacts. Sequence relay for mechanical control. Reverse-phase relay on all polyphase installations. Emergency call bell for push-button elevators. Sidewalk—Slack-cable device for both drums. Sequence relay. Reverse-phase relay on all polyphase installations. Waterproof-type warning bell 5 in. diameter to operate automatically by movement of car and warning sign not more than 10 ft. above sidewalk. Sign to read: "Danger—Look out for rising Elevator."

Hatchway Enclosures: Passenger and Freight—In future installations, to be inclosed in fireproof material full height if shaft pierces more than one floor. Shafts more than 9 sq.ft. sectional area shall be inclosed with brick 8 in. thick, concrete (stone or cinder), terra-cotta (hollow), concrete (hollow), gypsum (hollow), 6 in. thick reinforced concrete (stone or cinder), 4 in. thick, expanded metal or wire lath and cement mortar finished 2½ in. thick. Shafts extending into top floor of non-fireproof buildings to extend 3 ft. above roof, top to be fireproofed and to have metal skylight ¾ area of shaft or in lieu of skylight a window of same area in side of shaft 3 ft. above roof. If shaft does not extend to top floor, top to be fireproofed. Grill not less than No. 10 gage or expanded metal No. 13 gage 1½-in. mesh straight bars 1 in. between may be used in fireproof stair well. Existing grills to be covered with wire mesh or wire glass. Elevator hatchways piercing one floor only, existing or future installations, may be inclosed with grill No. 10 gage, expanded metal No. 13 gage or ⅜-in. thick wood slats spaced 1 in. apart, 6 ft. high. Existing elevators in non-fireproof public buildings to have fireproof shaft. Bottom of future shafts and existing shafts altered, to have fireproof construction. If machine is located at bottom of shaft to be protected by substantial pit pan. Not more than two elevators in one shaft. If only two elevators in building, must be in separate shafts. Sidewalk—Not required unless rise is more than one story; then shaft to be same as for passenger and freight elevators.

Hatchway doors: Passenger—In existing and future installations, doors to be latched from shaft side (push-button both sides). In future installations keys to be provided to unlock doors from outside in emergency. All fireproof shafts to have fireproof doors. Only one opening permitted in each story, and above each other, except doors may be located adjacent or opposite each other if door latch is not more than 48 in. from car switch. If more than 48 in., opposite or adjacent openings at first and top floor only. Gate contact required on car gate away from operator and a constant attendant at first and top floors. Attendant is not required on push-button elevator. No offsets on inside of shaft. Factory buildings only, future and existing installations, doors to be properly constructed sliding, or combination slide and swing, or swinging doors equipped with contacts, or swinging doors manually operated, or self-closing with auxiliary gates. (See gate paragraph.) Freight—All fireproof shafts to have fireproof doors. (Doors in factory buildings only to be same as for passenger elevator.) Sidewalk—None required except at sidewalk unless elevator pierces more than one floor; then same as freight elevator.

Trapdoors: Passenger and Freight—In existing buildings automatic trapdoors and guards must be furnished in any un-inclosed hatch and arranged to form a substantial floor cover when closed. Sidewalk—At sidewalk level to open and close by action of car.

Motor-Room Enclosure: Passenger, Freight and Sidewalk—Inclosed in same material as elevator shaft, lighted and have fire-doors at opening. Free and safe access to all parts of machinery; 12 in. clearance at stop limit on machine and motor end. Future installations in existing buildings, if sufficient space cannot be obtained, Superintendent of Buildings will grant modification. If machine is under shaft, pit pan to be provided.

Operator: Competent operator at least 18 years of age.

Installations Prohibited: Future installations, no belt or chain-driven elevators permitted for passenger service. Future installations, no auxiliary freight compartments above, below or side or similar device permitted on either passenger or freight elevators. Power-driven friction grip device prohibited on hand-power elevator when capacity exceeds 800 pounds.

Repairs and Alternations: Parts changed or altered to any elevator must comply with rules for future installations. Hand-power elevators changed to power-driven to comply with rules for power-driven elevators, except existing wood guides may remain if rise is not more than 35 ft. Removing elevator from old shaft to new is regarded as a new installation and must comply to rules for new elevators. Changing motive power of elevators may be done (if load and speed are not changed) without changing other elevator material. If freight elevators are changed to passenger elevators, they must conform to rules for passenger as regards safeties, ropes, capacity, car, enclosure, gates, exits, doors and door openings and motive power. If shaft is not enclosed, shaft and doors shall be enclosed as required for new elevators. Existing elevator with safety in cross head may remain if governor is furnished in connection therewith.

Anthracite Investigations in Senate Committee

The export situation and the production end of anthracite formed the principal topics discussed at last week's hearings before the Senate committee investigating the increased price of coal. A. S. Learoyd, assistant to the president of the Lehigh Coal and Navigation Co., in the course of his testimony said: "It is very difficult for the producing companies to answer any questions as to what the consumer pays for coal. Retail margins vary, and rightly so, because the cost to one dealer is different from the cost to another dealer in another city." Mr. Learoyd quoted the Bureau of Labor statistics of the Department of Labor to show that anthracite at the mine has increased in cost 51.5 per cent. over the pre-war cost. Owing to the customary advance of ten cents a month, costs in August had increased 62 per cent. This, Mr. Learoyd pointed out, was much less than the increase in most of the other necessities of life. The cry against increases in coal prices, in the view of the operators, is due largely to the fact that coal is sold by the ton. The large unit makes the increase more noticeable than would be the case if coal were sold by the pound, or even by the hundredweight.

In reply to questions Mr. Learoyd pointed out that coal-producing companies pursue the policy of declining to sell direct to the consumer. In support of this policy, he said that the retailer is a necessity in the distribution of coal. In addition to the difficulties presented by having to keep a multitude of small accounts, the operators feel, Mr. Learoyd said, that it is unfair to sell coal direct. The larger consumers would buy their coal direct if permitted to do so, but at least 50 per cent. of the population would find it impracticable or impossible to avail themselves of that privilege. This would mean that retailers would have to assess on this 50 per cent. of the population the total amount of their

overhead and fixed charges, with the result that the poor people would be very adversely affected. It is by far preferable to distribute all overhead, taxes and other costs over 100 per cent. of the consumers in the community. The anthracite operating companies, he declared, are interested in keeping the price of the domestic sizes of the coal just as low as possible.

A report reached the committee that "in his wildest dreams no retail man ever hoped for such profits as the Government gave him." The report as to excessive profits was based on statements attributed to President Lloyd, of the Retail Coal Association of Pennsylvania. Mr. Learoyd regarded any such interpretation of Mr. Lloyd's remarks as unwarranted. What Mr. Lloyd did say, he declared, was "that the Government had done the retailer the greatest service by enabling him to know what his costs are; not to make money, but to keep his books, to figure his investment, his taxes and his overhead in such a way as to know what his costs are. I have yet to hear of a retailer who grew rich through profits made during the war. The retail trade as a whole made some money. Prior to the war a lot of them lost money because they did not keep their books properly."

Anthracite coal producers, Mr. Learoyd stated, while declining to sell direct to individuals, will sell to any coöperative organization, because such an association is a dealer. Whether a profit is made in their subdistribution is a matter that would not be taken into consideration by the operators.

S. D. Warriner, the president of the Lehigh Coal and Navigation Co., told the committee that anthracite is facing very dangerous competition in the use of gas, oil and coke. New houses, he said, are being equipped for the use of other fuels than anthracite.

Broken coal, Mr. Learoyd pointed out, is not in great demand this year because of the reduced activity of industrial and gas plants. He gave the demand as being about one-half that of last year. In spite of the decreased production this year, he said, there is in storage 1,200,000 tons of No. 1 buckwheat and smaller sizes. "We are ready to ship 400,000 tons of pea coal just as rapidly as it can be loaded."

Charles E. Lord

Charles E. Lord, general patent attorney of the International Harvester Co., died Sept. 25 at the Alexian Brothers Hospital, Chicago, from injuries sustained at the company's Deering Harvester Works the day previous. With an inventor of a sand-molding device, he was on his way to the foundry when the automobile in which he was going through the plant was struck by a switch engine. The machine was proceeding at a moderate speed when the switch engine came in sight, and at an apparently safe distance from the track the driver attempted to stop the car. Setting the brake tight locked the wheels and on a slippery, greasy pavement the car slid onto the track. The engine hooked on to the part of the automobile and dragged it for a distance of about twenty feet. Being on the side of the approaching engine, Mr. Lord attempted to get out of the car and at the time of the impact was knocked from the running board and dragged along with the machine, the rear end of the latter swinging around and closing the V between it and the engine, with Mr. Lord between. With severe internal injuries and a fracture of the skull at the base of the brain, he died twelve hours later.

Since 1912 Mr. Lord had been the head of the Harvester patent department. Previously, he had been an examiner in the Patent Office at Washington, and later was in the service of the General Electric Co. at Schenectady, N. Y., the Bullock Electric Co. at Norwood, Ohio, and the Allis-Chalmers Manufacturing Co. at Milwaukee, Wis., all of his work having relation to the patent requirements of these companies.

Having graduated from the Boston School of Technology in 1898, and later in a course of law at Washington, Mr. Lord brought into his work the rare combination of an expert engineer and a lawyer familiar particularly with the laws concerning patents, although well posted in other points of the law. Patient, steady attention to his angle of the business resulted in an even flow of success. He was a man of broad views, altruistic, modest and charitable in his attentions toward others. He was a capable adjuster and attained an enviable reputation in his line of work.

Last season Mr. Lord was chairman of the Chicago Section of the American Society of Mechanical Engineers. He was also a member of the Society of Automotive Engineers, Patent Lawyers' Association of Chicago, the American Bar Association and the American Institute of Electrical Engineers. Locally, he also belonged to the Old Colony Club, the University Club, and the North Shore Golf Club. He was born on Oct. 31, 1875, at Somerville, Boston, Mass., and is survived by a widow and three children.

Operating Performance in Electric Railway Power Plants

From data furnished by various electric railway companies the following information has been compiled by the Power Generation Committee of the American Electric Railway Engineering Association and was contained in the committee's report read at the convention held at Atlantic City, N. J., Oct. 6-10, 1919.

Curves were plotted from data furnished by 21 different companies to show the relation between plant efficiency and capacity. From these curves the values given in Table I were obtained. It may be noted that while the larger plants have the greater efficiencies, the increase in efficiency is much more rapid among the smaller plants.

Table II gives an idea of the distribution of the cost in plants of various size.

Table III shows a comparison of costs in the same plant for the fiscal year 1916 as against 1918. This plant had a two-hour capacity of 9300-kw.

Table IV gives the same information for a plant having a two-hour capacity of 24,000 kw.

TABLE I. RELATION OF SIZE OF PLANT TO EFFICIENCY

Two-Hour Plant Capacity	B.t.u. per Kw.-Hr. Generated	Thermal Efficiency, Per Cent.
Below 1,000 kw	90,000 to 80,000	About 4
1,000 to 3,000 kw	80,000 to 56,000	4.0 to 6.1
3,000 to 5,000 kw	56,000 to 43,000	6.1 to 8.0
5,000 to 10,000 kw	43,000 to 35,000	8.0 to 9.6
10,000 to 20,000 kw	35,000 to 33,500	9.6 to 10.0
20,000 to 50,000 kw	33,500 to 31,000	10.0 to 11.0

TABLE II. RELATION OF SIZE OF PLANT TO VARIOUS ITEMS OF COST

	Aver. Fuel Cost per Kw.-Hr., Cents	Aver. Labor Cost per Kw.-Hr., Cents	Aver. Maint. Cost per Kw.-Hr., Cents	Aver. Misc. Cost per Kw.-Hr., Cents	Aver. Total Cost per Kw.-Hr., Cents
3,000 kw. and less (6 plants)	1.85	0.43	0.13	0.15	2.56
3,000 to 5,000 kw. (5 plants)	0.96	0.25	0.09	0.15	1.45
5,000 to 10,000 kw. (4 plants)	0.77	0.15	0.08	0.05	1.05
10,000 to 20,000 kw. (9 plants)	0.76	0.14	0.10	0.05	1.05
20,000 to 50,000 kw. (10 plants)	0.75	0.11	0.07	0.05	0.08

TABLE III. COMPARATIVE COST FOR A SINGLE PLANT IN 1916 AND 1918

	1918	1916
Fuel cost per kw.-hr	$0.00539	$0.00222
Labor cost per kw.-hr	.00239	.00186
Maintenance per kw.-hr	.00053	.00042
Water, lubricants, etc., per kilowatt-hour	.00045	.00058
Total cost per kw.-hr	$0.00876	$0.00508

TABLE IV. COMPARATIVE COST FOR A SINGLE PLANT IN 1916 AND 1918

	1918	1916
Fuel cost per kilowatt-hour	$0.00749	$0.00320
Labor cost per kilowatt-hour	.00105	.00070
Maintenance cost per kilowatt-hour	.00103	.00360
Water, lubricants, etc., per kilowatt-hour	.00017	.00011
Total cost per kilowatt-hour	$0.00974	$0.00437

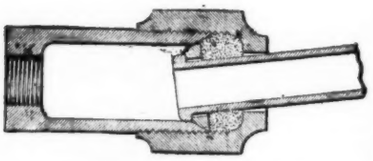
Condensed-Clipping Index of Equipment

Clip, paste on 3 x 5-in. cards and file as desired

Union, Berryman Expansion

W. F. Berryman, Middletown, Ohio.

"Power," July 22, 1919



The union consists of two pipe diameters, one fitting within the other. One pipe is made with a flanged end, the outer edge of which is rounded. A gland surrounds this pipe. A packing ring with a rounded outer face seats on a like surface of the casing. The flat sides of the packing ring compress a packing substance when the gland is screwed up tight. As the opening in the gland is larger than the pipe, the latter can be considerably out of line and still maintain a tight joint.

Coupling, Uniflex Shaft

Uniflex Coupling Co., 246 Chestnut St., Philadelphia, Penn.

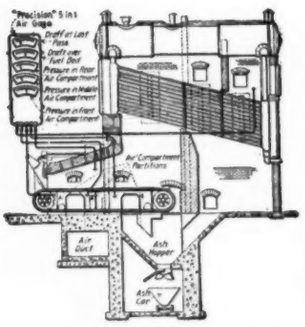
"Power," July 22, 1919

This shaft coupling comprises two members. The shaft members are made with jaws which engage each other through a block that fits in between the face of the jaws. This makes a coupling that is insulated, shock-absorbing, and does not require lubrication. The coupling can be made self-adjusting for wear and can be operated in either direction. It is designed for any size shaft, horsepower and revolutions per minute.

Gage, Five in One Draft

Precision Instrument Co., Detroit, Mich.

"Power," July 29, 1919



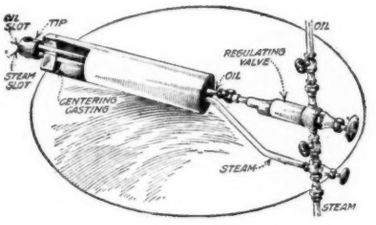
This instrument consists of five gages so connected to the boiler setting as to tell the pressure in the first and third air compartments, the draft over the fuel bed and the draft in the last pass. The standard readings for the stoker draft are 0 to 2 in. of water, 1 in. vacuum to 1 in. pressure for the combustion chamber, 0 to 6 in. for the front air compartment, 0 to 4 for the center air compartment and 0 to 1½ in. for the rear air compartment. Variation in pressure and vacuum are transmitted by diaphragms to a vertical adjustable plunger attached to a horizontal shaft by means of a link or lever.

Burner, Lockett Flat-Flame Oil

A. M. Lockett & Co., Ltd., 533 Baronne St., New Orleans, La.

"Power," Aug. 19, 1919

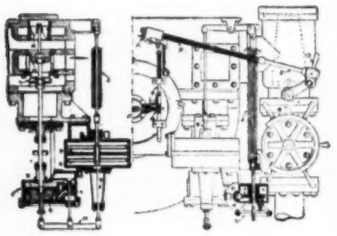
This burner is of the so-called fishtail flat-flame type. The only wearing part is the tip, which is made of steel and is easily cleaned by removing one plug. The oil pipe is straight and can be cleaned without dismantling the burner. It is provided with a steam bypass for blowing out the tip and strainer when shutting down. Oil is discharged through a slot instead of an annular ring.



Governor, Pneumatic Steam Turbine

Ridgway Dynamo and Engine Co., Ridgway, Penn.

"Power," Aug. 19, 1919



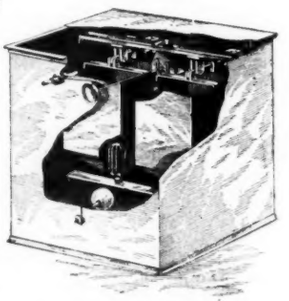
In this governor the metal weights commonly used on governors are replaced by air, which also replaces the connecting linkage levers, etc., between the centrifugal element and the valves. The only running part is a plain disk with vanes on the side of it, which is bolted to the shaft. Air forms the connecting medium between it and the other moving parts, and these move only on a change of speed due to a change of load. A small pilot valve and piston move in oil and should therefore last indefinitely. The only work to be performed by the air piston is to operate a small ⅝-in. diameter pilot valve which is balanced and floats in oil. The air force on two pistons is about 150 lb., thus making the pneumatic action of the governor powerful and reliable. The air pressure generated by the fan is as the square of the speed.

Water Weigher, Turner Automatic

The Water Weighing Machine Co., Inc., Piqua, Ohio.

"Power," Aug. 19, 1919

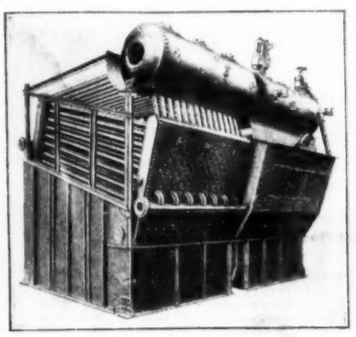
A steel tank containing two cast-iron rectangular weighing buckets with hopper bottoms and open tops. A float and valve maintains a constant water level in the storage tank. Water flows into one of the buckets and when filled to a predetermined height, the weight of water overcomes a counterweight; the bucket descends and by means of a lever the valve is moved, causing water to flow into the other bucket. The descent of the bucket also causes a ball valve to strike a stop, which pushes the valve from its seat and its buoyancy causes it to rise to the top of its cage. Water then discharges through the valve opening, and when the bucket is empty the counterweight again comes to normal position, and the water continues to discharge until empty.



Heine Marine Cross-Drum Boiler

Heine Safety Boiler Co., St. Louis, Mo.

"Power," July 29, 1919

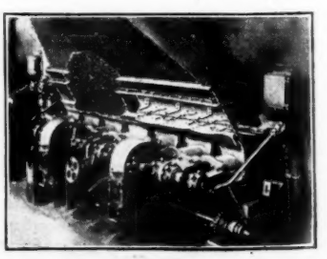


This marine boiler is of a cross-drum type and consists essentially of two flat steel headers and a cylindrical feed drum. The main bank tubes are 3½ in. diameter and when the boiler is in position are inclined at an angle of 16 deg. to the horizontal. The feed drum varies from 36 to 18 in. in diameter. The seam is double-riveted, double-butt strapped longitudinal. The drum is fitted with a deflection plate. A scum pan of the "dish" type is also used, and surge plates are installed. There is a perforated dry pipe, the area of the slot exceeding the area of the outlet opening.

Agitator, Negus-Tiffany Coal

W. E. Ellis & Co., Haverhill, Mass.

"Power," Aug. 12, 1919



This stoker agitator consists of agitating arms, the number depending upon the size of the stoker and the number of stoker retorts. These arms are secured to a shaft that reaches across the bottom of the hopper, the agitator coming midway between the stoker plungers. One end of the agitator rod is connected by means of a bell crank and rod to the stoker ram shaft. The rod connection to the bell crank has a two-way motion, obtained by a special design of joints. The crank has a throw of 3 in. from center to center, which gives a 6-in. movement of the belt crank. The movement of the agitating arms across the bridge of coal formed by the stoker plungers undermines the packed coal and permits the plunger boxes to fill ready for the next forward movement of the plunger. This keeps a full charge of fuel in front of the rams.

Patented Aug. 20, 1918